Table A.8-2. Linear regression coefficients and correlation coefficients for temperature vs dye concentration from data taken along section 1f (see Fig. A.8-1) on 24 October 1977 (from Ref. A.8-1) on 24 October 1977 (from Ref. 62). See text for definition of headings.

| Run No. | Time | Depth = 1m | | | | | Depth = 4m | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | b | a | r | $D_p^{-1}$ | $T_p$ | b | a | r | $D_p^{-1}$ | $T_p$ |
| 1 | 0925 | 7.46 | 13.30 | 0.938 | 0.497 | 16.94 | 6.51 | 13.88 | 0.925 | 0.477 | 17.04 |
| 2 | 0932 | 7.38 | 13.21 | 0.992 | 0.510 | 16.90 | 6.34 | 13.86 | 0.978 | 0.492 | 16.91 |
| 3 | 0957 | 8.29 | 13.15 | 0.926 | 0.492 | 17.11 | 7.20 | 13.66 | 0.953 | 0.473 | 17.01 |
| 4 | 1006 | 6.17 | 13.71 | 0.848 | 0.411 | 16.25 | 1.57 | 15.09 | 0.709 | 0.344 | 15.82 |
| 6 | 1108 | 7.58 | 13.68 | 0.967 | 0.555 | 17.69 | 7.43 | 13.92 | 0.963 | 0.515 | 17.65 |
| 7 | 1120 | 8.02 | 13.46 | 0.967 | 0.526 | 17.61 | 7.20 | 13.94 | 0.936 | 0.504 | 17.33 |
| 8 | 1127 | 8.14 | 13.51 | 0.961 | 0.535 | 17.64 | 7.36 | 13.86 | 0.956 | 0.503 | 17.49 |
| 9 | 1145 | 8.44 | 13.50 | 0.956 | 0.475 | 17.38 | 7.65 | 13.75 | 0.985 | 0.500 | 17.31 |
| 10 | 1153 | 7.43 | 13.81 | 0.964 | 0.473 | 17.34 | 8.11 | 13.78 | 0.995 | 0.463 | 17.40 |
| 11 | 1239 | 8.24 | 13.93 | 0.949 | 0.377 | 17.25 | 8.31 | 13.79 | 0.974 | 0.339 | 16.67 |
| 12 | 1252 | 7.67 | 14.08 | 0.980 | 0.450 | 17.61 | 8.48 | 13.73 | 0.988 | 0.426 | 17.16 |
| 13 | 1300 | 7.61 | 14.04 | 0.982 | 0.441 | 17.08 | 8.45 | 13.79 | 0.976 | 0.426 | 17.08 |
| 15 | 1338 | 7.42 | 13.94 | 0.946 | 0.415 | 17.18 | 8.41 | 13.89 | 0.984 | 0.382 | 16.87 |
| 16 | 1347 | 7.57 | 13.85 | 0.934 | 0.485 | 17.41 | 8.72 | 13.73 | 0.965 | 0.411 | 17.11 |
| 17 | 1410 | 7.57 | 13.89 | 0.950 | 0.444 | 17.25 | 7.64 | 14.06 | 0.971 | 0.422 | 17.08 |
| 18 | 1436 | 6.09 | 13.96 | 0.878 | 0.422 | 16.64 | 6.06 | 13.98 | 0.945 | 0.410 | 16.98 |
| 19 | 1444 | 7.12 | 14.11 | 0.908 | 0.484 | 17.30 | 8.02 | 13.99 | 0.966 | 0.441 | 17.34 |
| 20 | 1500 | 9.01 | 13.69 | 0.928 | 0.401 | 17.29 | 9.21 | 13.75 | 0.948 | 0.347 | 16.79 |
| 21 | 1516 | 8.76 | 13.81 | 0.975 | 0.407 | 17.34 | 9.26 | 13.88 | 0.971 | 0.382 | 17.31 |
| 22 | 1540 | 8.05 | 13.89 | 0.979 | 0.433 | 17.31 | 9.07 | 13.85 | 0.972 | 0.385 | 17.11 |
| 23 | 1549 | 6.46 | 14.40 | 0.982 | 0.363 | 16.77 | 7.75 | 14.06 | 0.972 | 0.344 | 16.59 |

Table A.8-2. Continued.

| Run No. | Time | Depth = 1m | | | | | Depth = 4m | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | b | a | r | $D_p^{-1}$ | $T_p$ | b | a | r | $D_p^{-1}$ | $T_p$ |
| 24 | 1612 | 7.35 | 14.03 | 0.987 | 0.437 | 17.19 | 8.07 | 14.07 | 0.981 | 0.358 | 16.95 |
| 25 | 1621 | 8.08 | 13.83 | 0.962 | 0.419 | 17.21 | 8.08 | 14.01 | 0.962 | 0.381 | 17.08 |
| 26 | 1643 | 8.84 | 13.69 | 0.930 | 0.354 | 16.86 | 6.90 | 14.36 | 0.893 | 0.324 | 16.69 |
| 27 | 1651 | 8.18 | 13.78 | 0.958 | 0.396 | 17.03 | 7.72 | 14.11 | 0.962 | 0.337 | 16.71 |
| 28 | 1713 | 6.45 | 14.39 | 0.907 | 0.378 | 16.83 | 6.11 | 14.55 | 0.925 | 0.346 | 16.67 |
| 29 | 1722 | 5.66 | 14.45 | 0.962 | 0.340 | 16.34 | 4.65 | 14.82 | 0.938 | 0.332 | 16.33 |
| 30 | 1730 | 4.47 | 14.82 | 0.836 | 0.350 | 16.31 | 4.07 | 15.02 | 0.907 | 0.312 | 16.20 |
| 31 | 1737 | 6.45 | 14.39 | 0.942 | 0.605 | 18.18 | 7.13 | 14.30 | 0.938 | 0.555 | 18.21 |

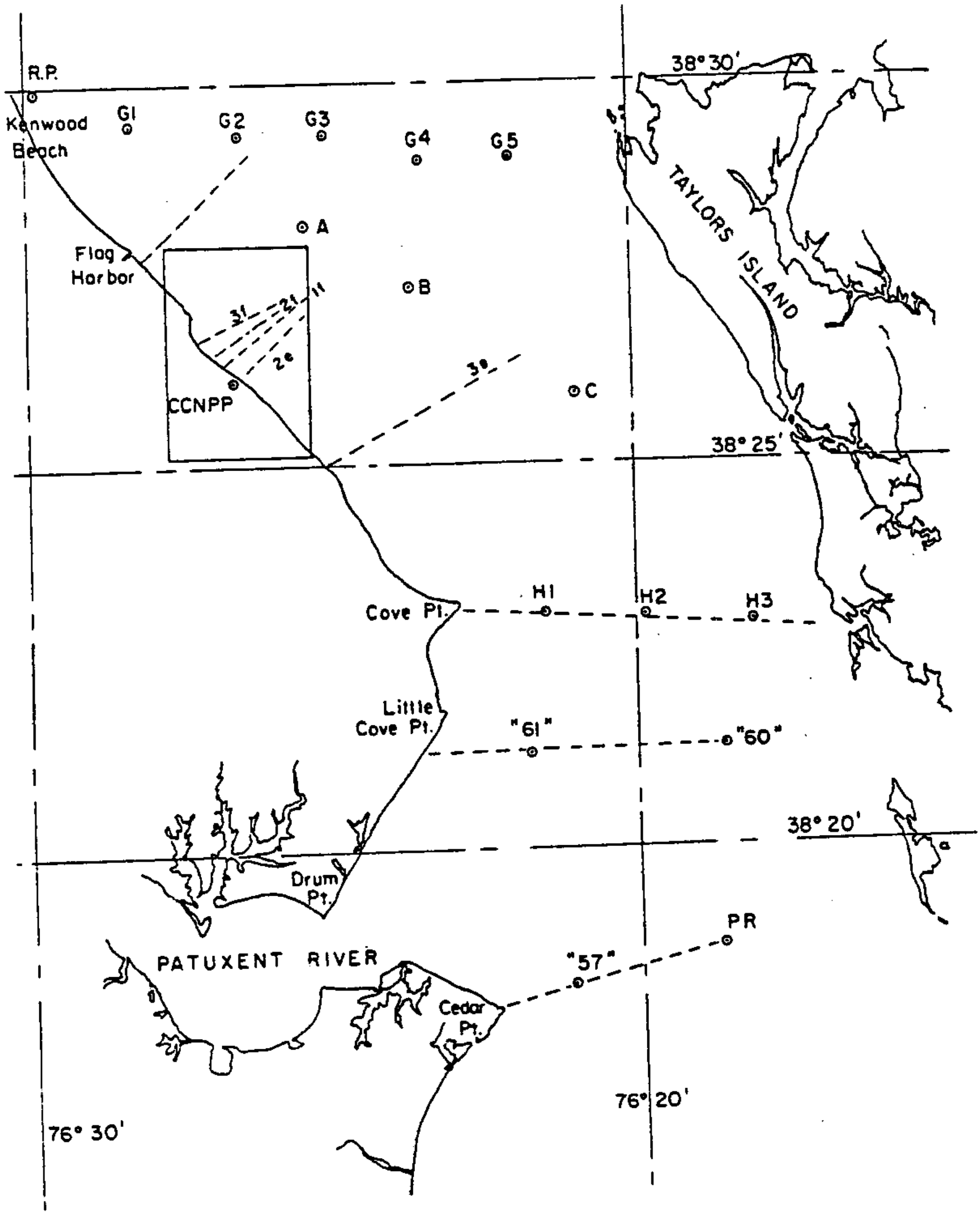


Figure A.8-1. Chart of a segment of the Chesapeake Bay centered on Cove Point showing the locations of current meter moorings, of vertical temperature/salinity/dye concentration stations, and of fluorescent dye and temperature sections (from Ref. 62).

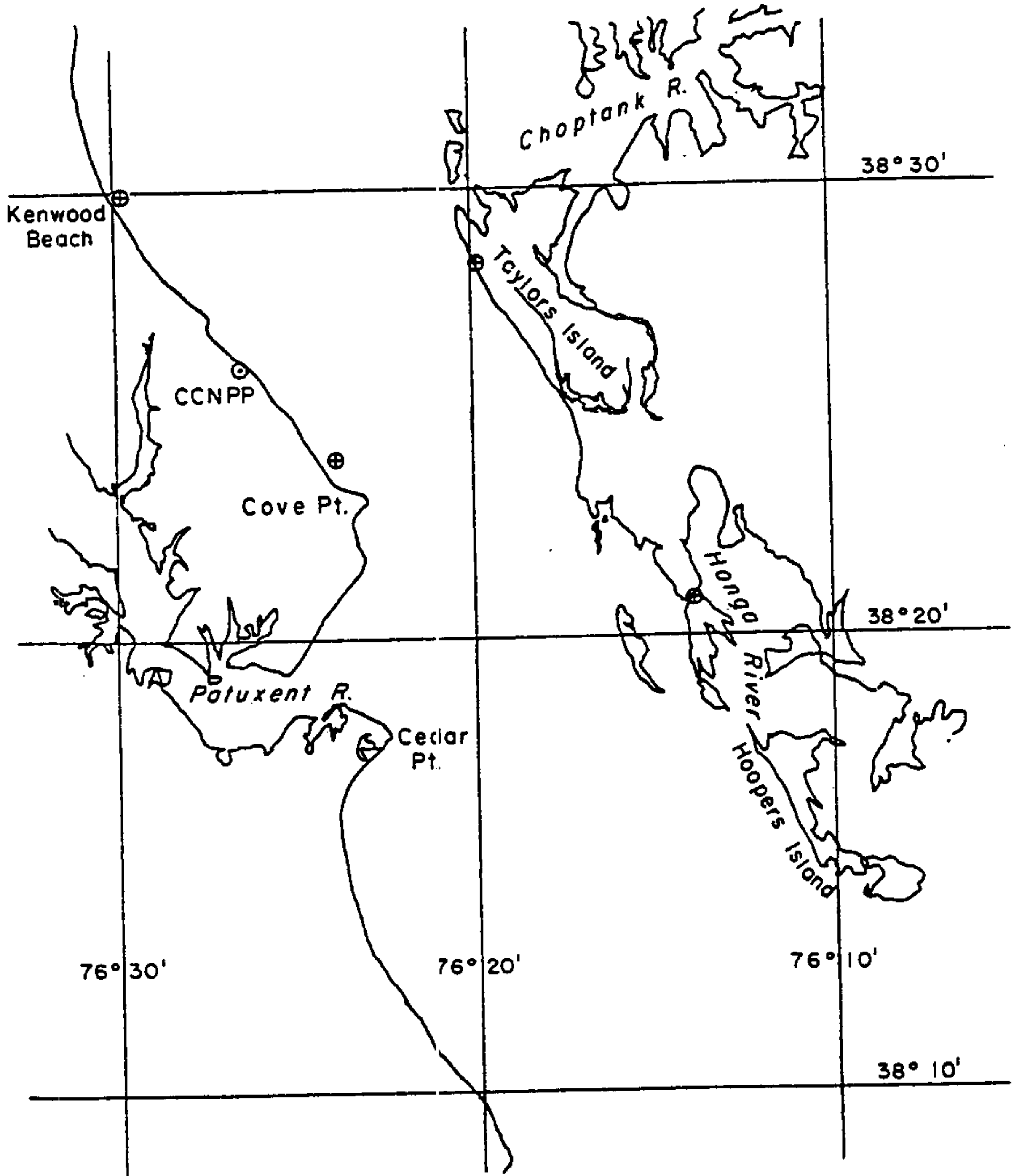


Figure A.8-2. Chart of a segment of the Chesapeake Bay centered on Cove Point showing the locations of the tide gauges (⊕) installed for this study (from Ref. 62).

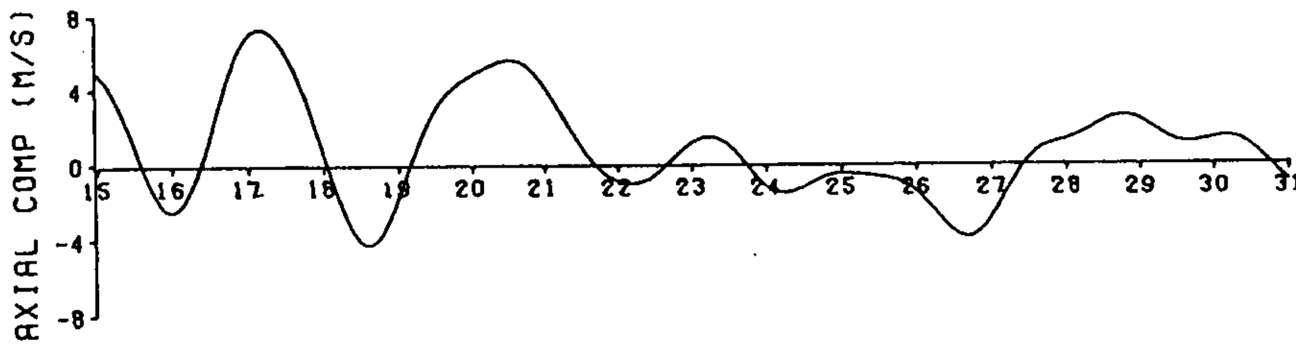


Figure A.8-3. Low-low pass filtered axial component of the wind velocity over a 2-week period (from Ref. 62).

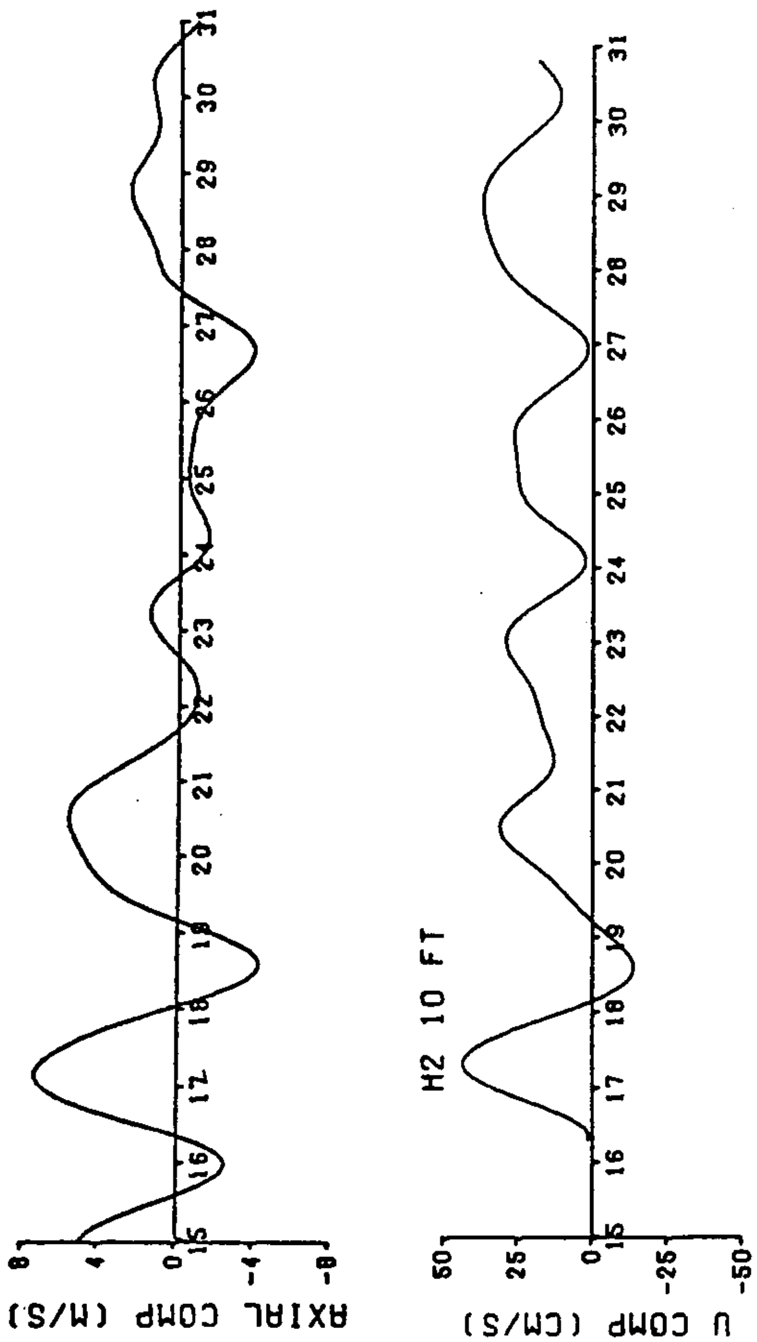


Figure A.8-4. Low-pass filtered longitudinal component of the wind velocity (upper) and of the current velocity at Station H2 at a depth of 10 feet (lower) over a 2-week period (from Ref. 62).

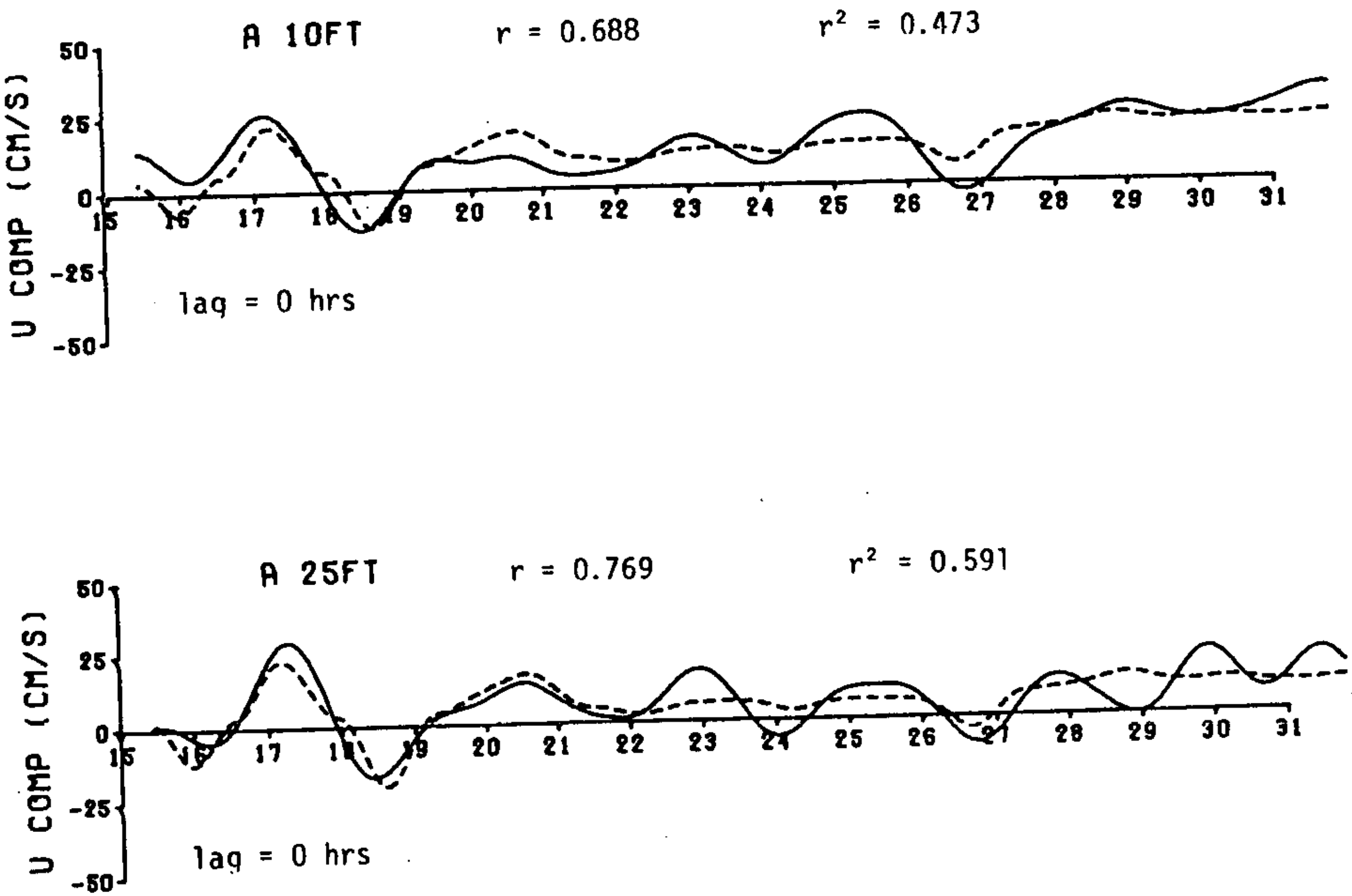


Figure A.8-5. Low-low pass filtered longitudinal component of the current velocity as observed (solid line) and as computed from the linear regression equation on the square of the low-pass wind filtered longitudinal component of the wind velocity (dashed line) over a 2 week period (from Ref. 62).

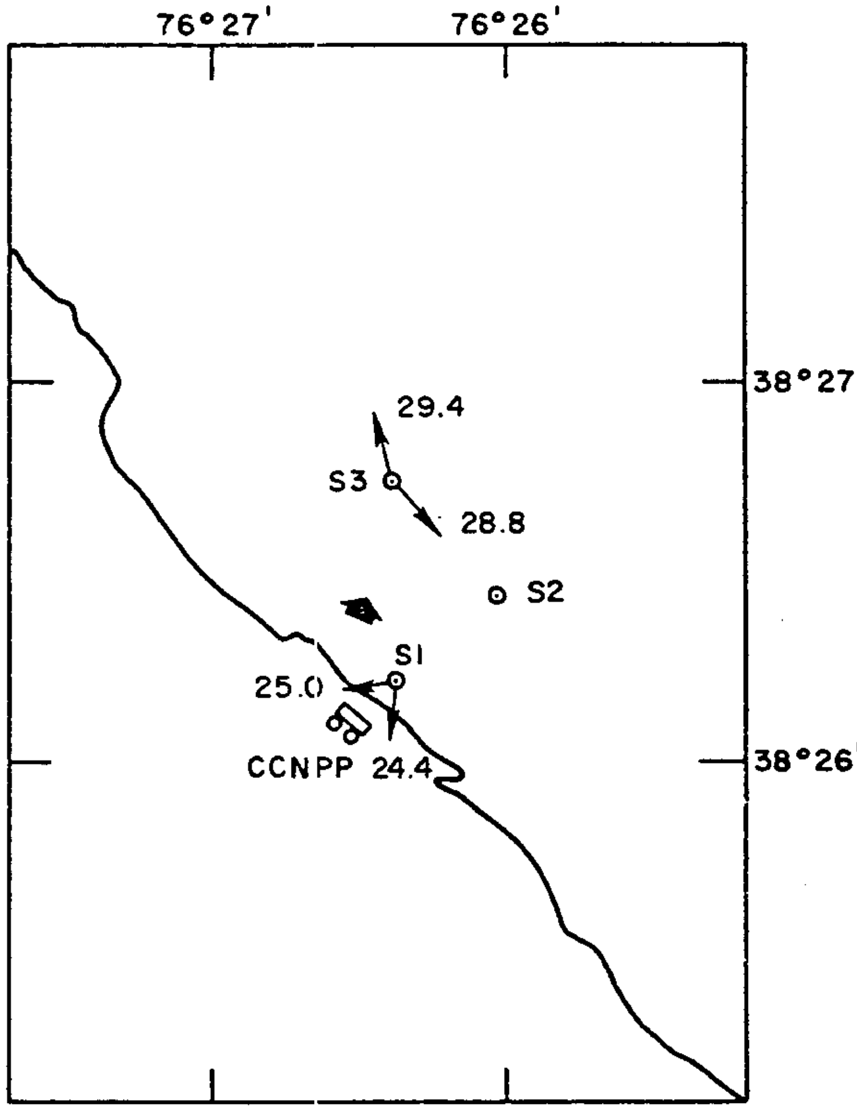


Figure A.8-6. Vectors indicating the predominant ebb direction and maximum ebb tidal current speed ($cm \cdot s^{-1}$) and the predominant flood direction and maximum flood tidal current speed ($cm \cdot s^{-1}$), in the vicinity of the Calvert Cliffs Nuclear Power Plant, at a depth of 28 feet for Station S1 and 25 feet for Station S3. Thick, short arrow indicates location of discharge structure and direction of discharge channel (from Ref. 62).

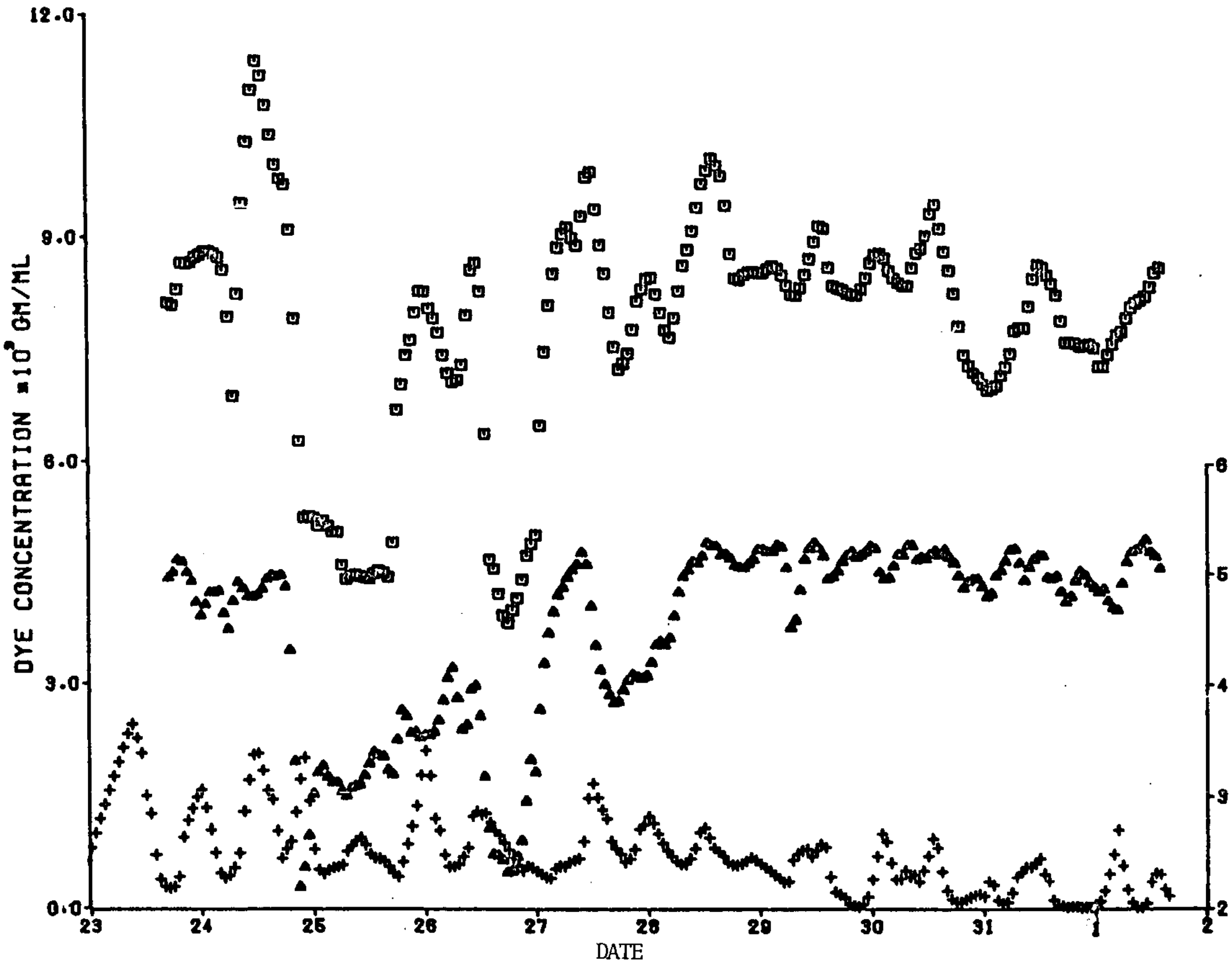


Figure A.8-7. Concentration of the tracer dye, expressed as grams of undiluted dye solution per $10^9$ grams of mixture, in the condenser cooling water intake (+) and discharge (⊡) of the Calvert Cliffs Nuclear Power Station, and the temperature rise across the condensers (▲), plotted against time for the period of the tracer dye study (from Ref. 62).

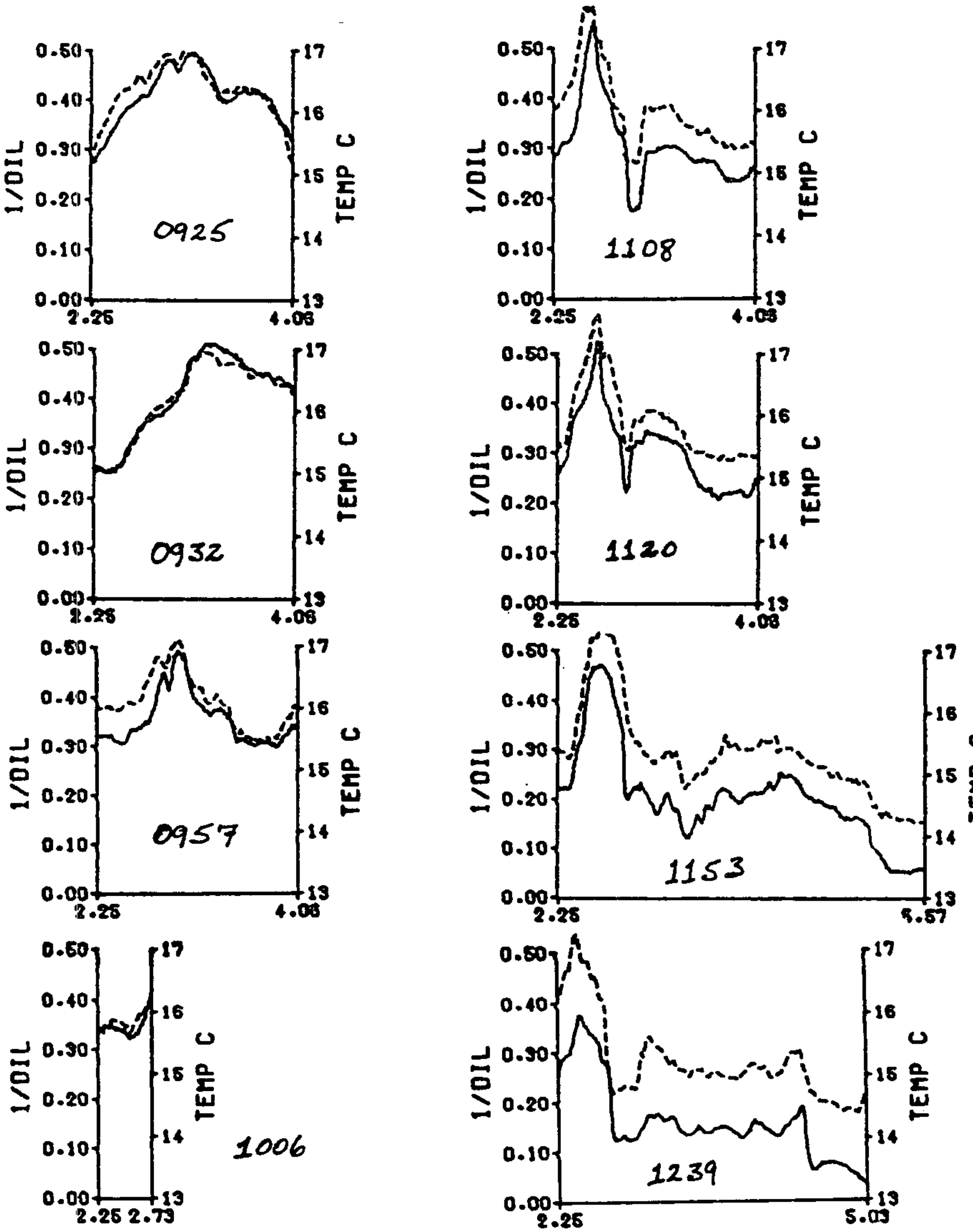


Figure A.8-8. Variation of relative dye concentration, expressed as inverse dilution (solid line), and of temperature (dashed line), along Section 1f (see Fig. A.8-1), at 1 meter depth on 24 October 1977. The starting time for each run is entered on the graph depicting that run (from Ref. 62).

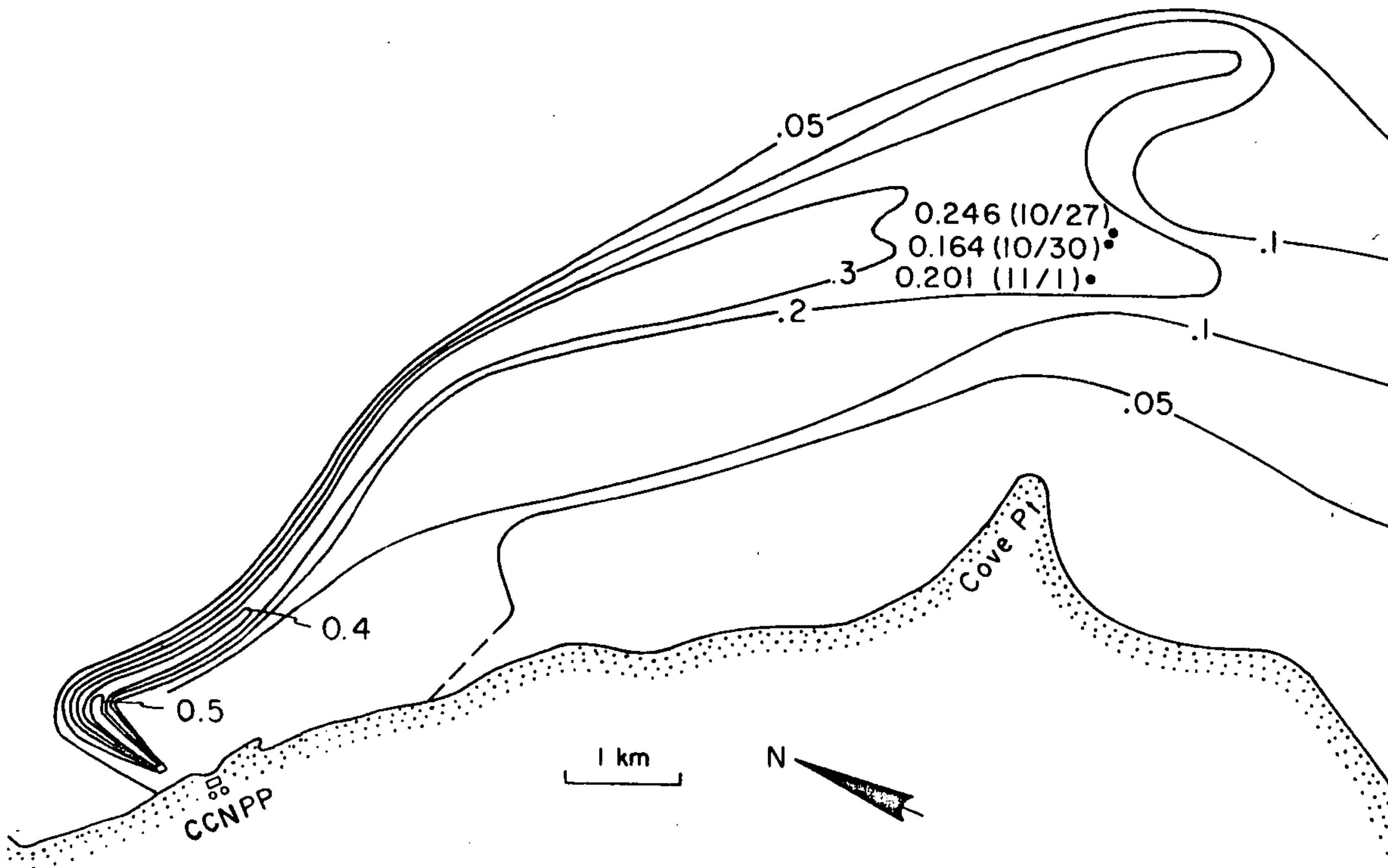


Figure A.8-9. Distribution of maximum observed inverse dilution of the effluent from the Calvert Cliffs Nuclear Power Station under conditions of unusually strong and prolonged ebb flows (from Ref. 62).

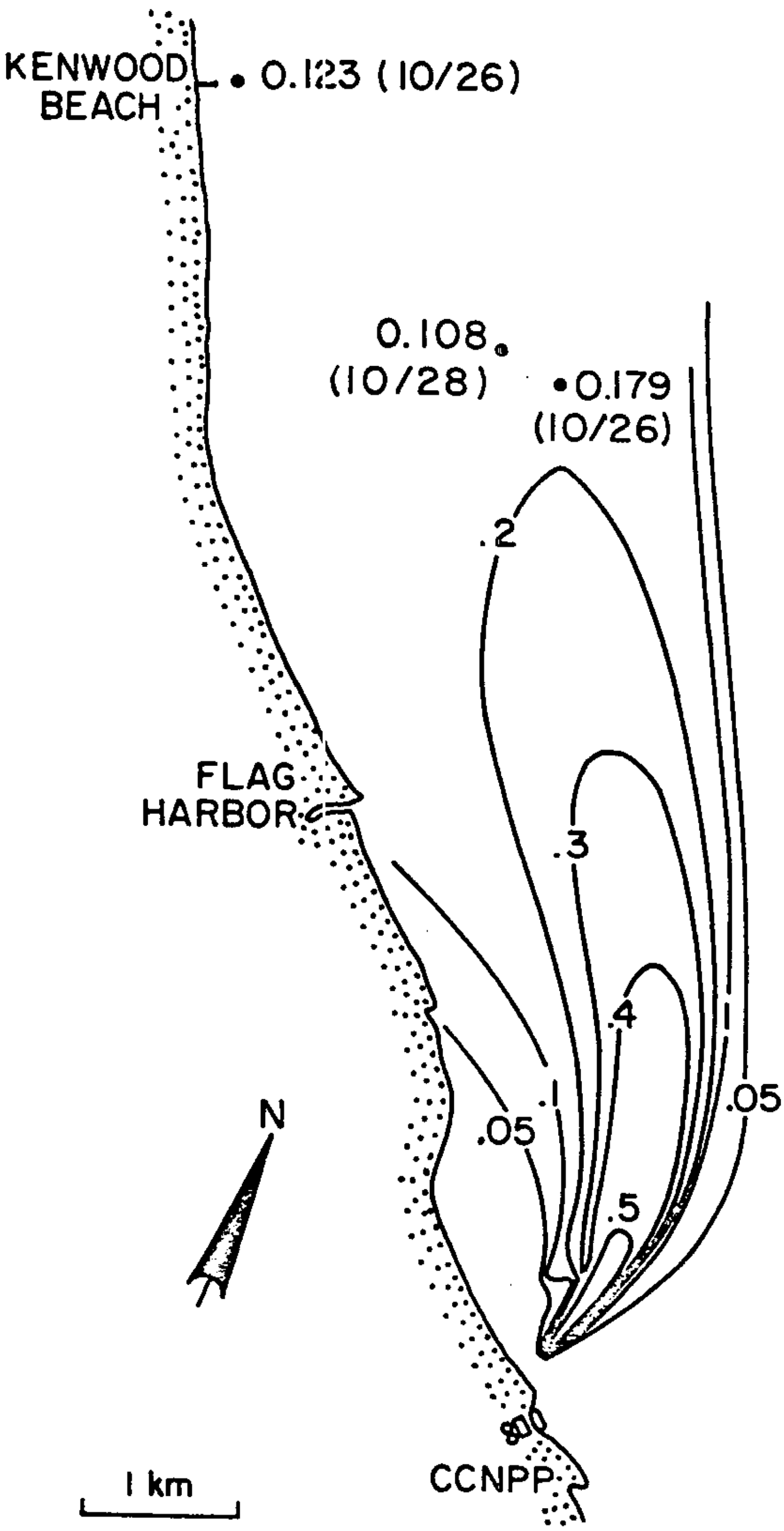


Figure A.8-10. Distribution of maximum observed inverse dilution of the effluent from the Calvert Cliffs Nuclear Power Station under conditions of normal flood flow (from Ref. 62).

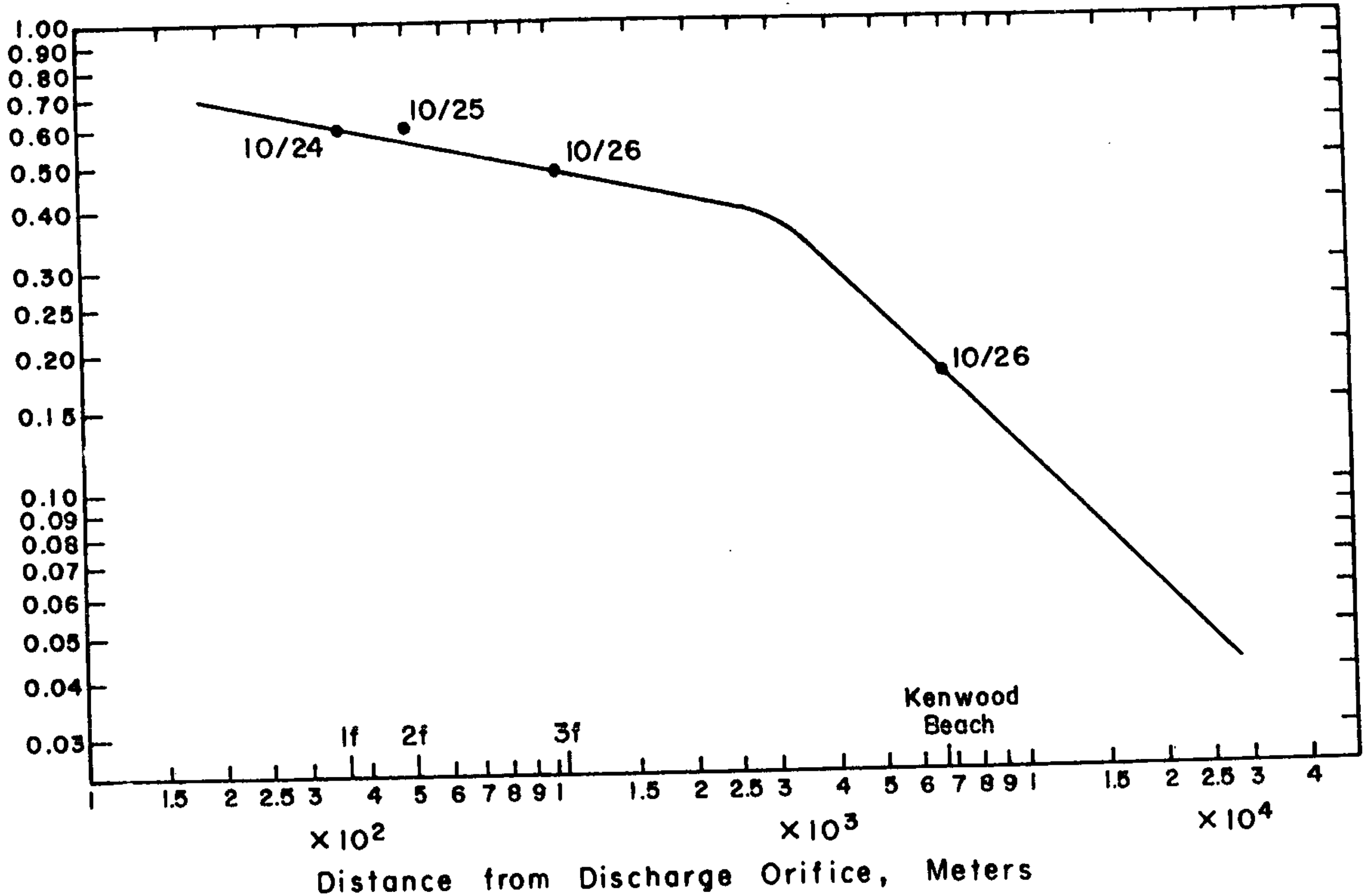


Figure A.8-11. Maximum observed values of the peak inverse dilution with distance from the discharge orifice as measured along the axis of the effluent plume, for conditions of unusually strong and prolonged ebb flows (from Ref. 62).

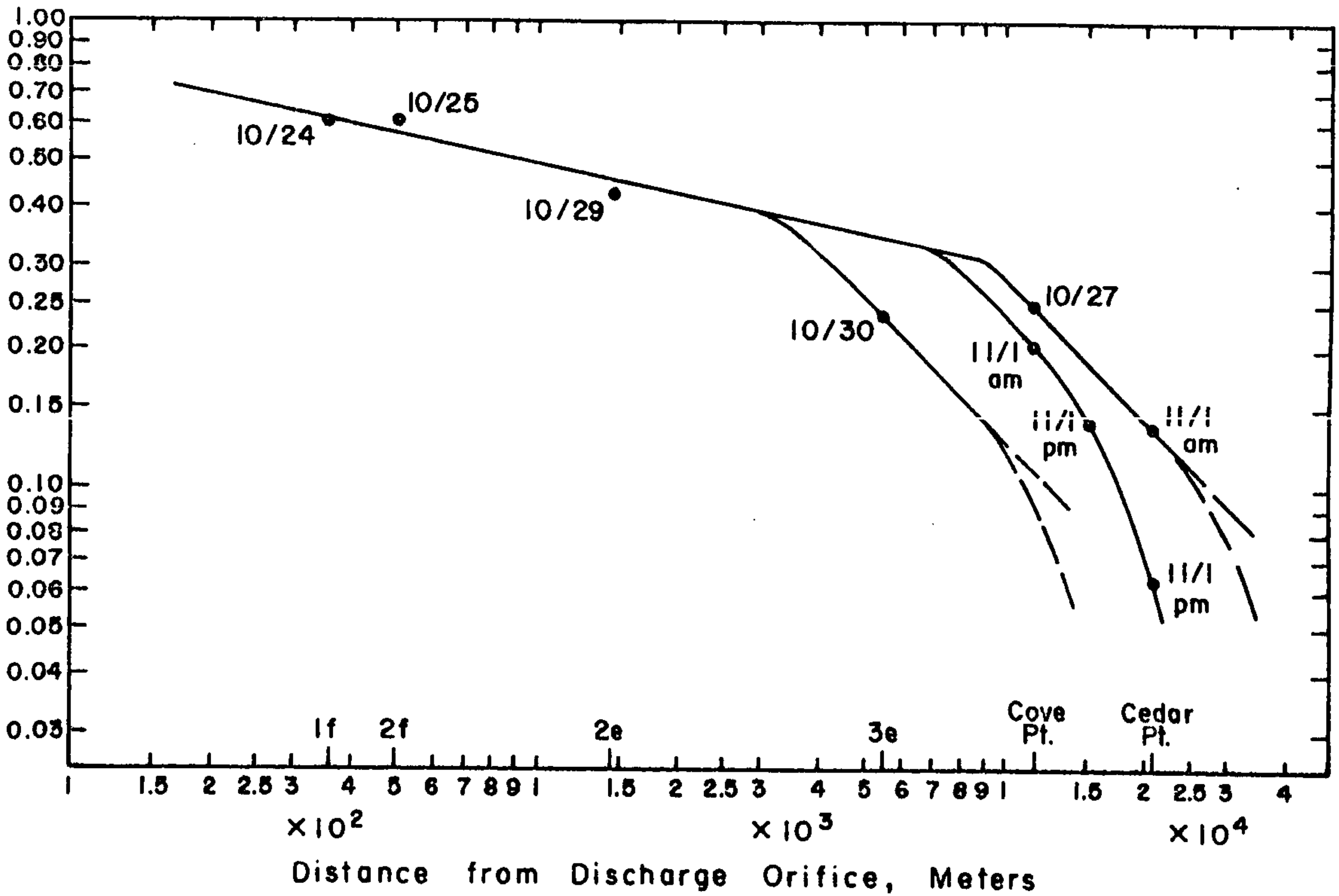


Figure A.8-12. Maximum observed values of the peak inverse dilution with distance from the discharge orifice as measured along the axis of the effluent plume, for conditions of normal flood flows (from Ref. 62).

# APPENDIX A.9. - PLUME DYE STUDY

(ANSP)

## A.9.1. Objective

To determine the size, shape, and location of the thermal plume under different environmental conditions.

## A.9.2. Data Source

Refs. 167.

## A.9.3. Study History

One-year study, with surveys in April-May and July-August 1979.

## A.9.4. Sampling Methods

- Rhodamine WT dye was released into the cooling water flow for 8 days at a rate proportional to the waste heat discharged.
- Zigzag courses were traversed over the plume by 2 vessels, one sampling at the surface and the other at 3 depths, and the presence of dye was determined using fluorometers; 8 plume maps were made in April, and 9 were made in August.
- Three current meters were set in 40 ft of water off the plant site at 5-, 20-, and 30-ft depths.

## A.9.5. Analysis

- Tests to establish correlations between dye concentration and temperature were run.
- Background fluorescence was characterized by its mean median range and 90% confidence limits.
- Dye concentrations were converted to excess temperatures using the equation

$$\theta = T_h - T_a = (T_{h_o} - T_a) \frac{C/\Gamma}{(C/\Gamma)_o}$$

where

$\theta$ = excess temperature
$T_h$ = observed temperature
$T_a$ = ambient temperature

$T_{h_o}$ = discharge temperature
$C$ = dye concentration in water
$\Gamma$ = concentration of the original dye solution.

- Excess temperatures were mapped.
- Frequency distributions of flood and ebb tidal excursions, derived from current meter data, were plotted.
- Compliance with Maryland Water Quality Regulations is addressed.

### A.9.6. Results

- Areas and maximum radial extents of April plumes are presented in Tables A.9-1 and A.9-2; recirculation ranged from 0 to 15%; tidal excursion distances are shown in Figs. A.9-1 and A.9-2.
- Areas and maximum radial extents of August plumes are presented in Tables A.9-3 and A.9-4; background fluorescence in August was twice as variable as in April; recirculation could not be monitored because of equipment problems. Similarly, complete current meter data were not available.
- Plume data are summarized in Table A.9-5.
- Environmental conditions during the CBI dye study (see Appendix A.8) were shown to be unique relative to average conditions; thus, their observed plumes were not representative of average plumes.

### A.9.7. Significance and Critique of Findings

- Results of this study are consistent with all plume mappings other than that of CBI (Appendix A.8); however, they provide data to show that wind and tidal conditions during the CBI studies were unusual and that plume dimensions reported here are more representative of average conditions; this conclusion appears correct.
- The authors demonstrate that the plant operates within the discharge limits defined by Maryland Water Quality Regulations concerning mixing zones.

Table A.9-1. Summary of maximum radial extent (m) of specified excess temperature isotherms for the April 1979 surveys (from Ref. 167).

| | 4/15/79 | | 4/16/79 | 4/17/79 | | 4/18/79 | 4/19/79 | 4/20/79 |
|---|---|---|---|---|---|---|---|---|
| | Run # | Run # | Run # | Run # | Run # | Run # | Run # | Run # |
| θ | 1 | 2 | 2 | 1 | 4 | 1 | 2 | 1 |
| | | | | Z = 0.6 m | | | | |
| 4 | - | - | 220 | 160 | - | 280 | 120 | 180 |
| 3 | 360 | - | 260 | 700 | 580 | 500 | 340 | 600 |
| 2 | 720 | 1180 | 1020 | 1300 | 1600 | 1200 | 3060 | 4820 |
| 1 | 2400 | 2620 | 2280 | 4520 | - | 5300 | - | - |
| | Run # | Run # | Run # | Run # | Run # | Run # | Run # | Run # |
| | 1 | 2 | 2 | 1 | 3 | 1 | 2 | 1 |
| | | | | Z = 1 m | | | | |
| 4 | - | - | - | - | 340 | - | - | - |
| 3 | 560 | - | 500 | - | 660 | - | 460 | 460 |
| 2 | 1020 | 1420 | 1220 | 1000 | 1020 | 1240 | 2680 | 3780 |
| 1 | 1240 | 1500 | 4720 | - | - | - | - | - |
| | | | | Z = 3 m | | | | |
| 4 | - | - | - | - | 360 | - | - | - |
| 3 | 800 | - | 460 | - | 560 | - | 640 | 420 |
| 2 | 1000 | 1420 | 980 | 1060 | 960 | 1000 | 2560 | 1140 |
| 1 | 1220 | 3600 | - | - | - | - | - | - |
| | | | | Z = 6 m | | | | |
| 4 | - | - | - | - | 380 | - | - | - |
| 3 | 580 | - | 500 | - | 720 | - | 640 | 420 |
| 2 | 1140 | 1440 | 1040 | 1100 | 1040 | 1000 | 2280 | 1320 |
| 1 | 1500 | 1800 | - | - | - | - | - | - |

Note: (-) indicates isotherm could not be closed.

Table A.9-2. Summary of areas ($10^4 m^2$) contained within specified excess temperature isotherms for the April 1979 surveys (from Ref. 167).

| | 4/15/79 | | 4/16/79 | 4/17/79 | | 4/18/79 | 4/19/79 | 4/20/79 |
|---|---|---|---|---|---|---|---|---|
| | Run # | Run # | Run # | Run # | Run # | Run # | Run # | Run # |
| θ | 1 | 2 | 2 | 1 | 4 | 1 | 2 | 1 |
| | | | | Z = 0.6 m | | | | |
| 4 | - | - | 0.80 | 0.40 | - | 1.20 | 0.40 | 0.80 |
| 3 | 1.20 | - | 0.84 | 4.80 | 3.60 | 4.80 | 2.00 | 2.00 |
| 2 | 5.60 | 34.80 | 28.80 | 17.60 | 39.60 | 17.20 | 136.00 | 375.00 |
| 1 | - | - | - | 196.00 | - | 256.00 | - | - |
| | Run # | Run # | Run # | Run # | Run # | Run # | Run # | Run # |
| | 1 | 2 | 2 | 1 | 3 | 1 | 2 | 1 |
| | | | | Z = 1 m | | | | |
| 4 | - | - | - | - | 2.00 | - | - | - |
| 3 | 1.60 | - | 2.80 | - | 4.40 | - | 4.00 | 4.80 |
| 2 | 7.60 | 30.40 | 19.60 | 29.60 | 16.00 | 15.20 | 77.20 | - |
| | | | | Z = 3 m | | | | |
| 4 | - | - | - | - | 1.20 | - | - | - |
| 3 | 3.60 | - | 3.20 | - | 5.60 | - | 6.40 | 3.20 |
| 2 | 9.20 | 34.80 | 15.20 | 12.00 | 22.40 | 13.20 | 44.40 | 18.80 |
| | | | | Z = 6 m | | | | |
| 4 | - | - | - | - | 1.20 | - | - | - |
| 3 | 3.20 | - | 2.80 | - | 6.00 | - | 7.20 | 1.60 |
| 2 | 14.00 | 26.00 | 17.20 | 28.00 | 16.40 | 16.00 | 66.00 | 12.80 |

Note: (-) indicates isotherm could not be closed.

Table A.9-3. Summary of maximum radial extent (m) of specified excess temperature isotherms for August 1979 surveys (from Ref. 167).

| | 8/6/79 | | 8/7/79 | | 8/8/79 | | 8/9/79 | | 8/10/79 |
|---|---|---|---|---|---|---|---|---|---|
| | Run # | Run # | Run # | Run # | Run # | Run # | Run # | Run # | Run # |
| 0 | 2 | 3-4 | 3-4 | 6-7 | 2 | 3-4 | 2 | 3-7 | 1-7 |
| | | | | Z = 0.6 m | | | | | |
| 4 | 120 | - | 120 | - | 60 | 130 | 220 | - | 210 |
| 3 | 660 | 160 | 720 | 290 | 70 | 280 | 1020 | 80 | 280 |
| 2 | 760 | 680 | 1380 | 3940 | 300 | 1180 | 2480 | 320 | 1020 |
| 1 | - | - | - | - | 490 | - | 3550 | - | - |
| | Run # | Run # | Run # | Run # | Run # | Run # | Run # | Run # | Run # |
| | 1 | 5 | 2 | 3 | 2 | 3-4 | 3-4 | 5-6 | 2-4 |
| | | | | Z = 2.5 m | | | | | |
| 4 | - | - | 180 | - | # | - | - | - | - |
| 3 | - | - | 270 | 380 | # | 600 | 400 | 230 | 440 |
| 2 | - | - | - | 1040 | # | 1260 | - | 310 | 620 |
| 1 | - | - | - | - | # | - | - | - | - |
| | | | | Z = 4.0 m | | | | | |
| 4 | - | - | 200 | - | - | - | - | - | - |
| 3 | - | - | 380 | 660 | - | 530 | 390 | 320 | 380 |
| 2 | 890 | - | 620 | 1040 | 700 | 1200 | - | 420 | 880 |
| 1 | - | - | - | - | 800 | - | - | - | - |
| | | | | Z = 6.0 m | | | | | |
| 4 | - | - | 220 | - | * | - | - | - | - |
| 3 | - | - | 280 | 550 | * | 530 | 390 | 320 | 610 |
| 2 | 480 | 780 | 640 | - | * | 1280 | - | - | 930 |
| 1 | - | - | - | - | * | - | - | - | - |

NOTE: (-) indicates isotherm could not be closed; * indicates depth not plotted; # indicates all excess temperatures < 2°C.

Table A.9-4. Summary of areas ($10^4 m^2$) contained within specified excess temperature isotherms for August 1979 surveys (from Ref. 167).

| | 8/6/79 | | 8/7/79 | | 8/8/79 | | 8/9/79 | | 8/10/79 |
|---|---|---|---|---|---|---|---|---|---|
| θ | Run # 2 | Run # 3-4 | Run # 3-4 | Run # 6-7 | Run # 2 | Run # 3-4 | Run # 2 | Run # 3-7 | Run # 1-7 |
| Z = 0.6 m | | | | | | | | | |
| 4 | 0.20 | - | 0.64 | 0.32 | - | 0.40 | 0.60 | 0.72 | - |
| 3 | 2.24 | 0.48 | 11.12 | - | 0.16 | 1.60 | 1.68 | 8.08 | 0.16 |
| 2 | 39.92 | 7.68 | 49.94 | - | 1.20 | 12.96 | 7.28 | 62.56 | 1.04 |
| 1 | 106.88 | 574.00 | - | - | 4.96 | - | - | - | 4.00 |
| | Run # 1 | Run # 5 | Run # 2 | Run # 3 | Run # 2 | Run # 3-4 | Run # 3-4 | Run # 5-6 | Run # 2-4 |
| Z = 2.5 m | | | | | | | | | |
| 4 | - | - | 0.60 | - | # | - | - | - | - |
| 3 | - | - | 2.80 | 2.40 | # | 5.92 | 4.48 | 2.72 | - |
| 2 | - | - | - | - | # | 19.20 | 10.88 | - | - |
| 1 | - | - | - | - | # | - | - | - | - |
| Z = 4.0 m | | | | | | | | | |
| 4 | - | - | 0.64 | - | - | - | - | - | - |
| 3 | - | - | 3.28 | 5.44 | - | 4.88 | 2.32 | 0.80 | 2.40 |
| 2 | 7.36 | - | 12.56 | - | 10.88 | - | 9.28 | - | - |
| 1 | - | - | - | - | 3.92 | - | - | - | - |
| Z = 6.0 m | | | | | | | | | |
| 4 | - | - | 0.40 | - | * | - | - | - | * |
| 3 | - | - | 2.00 | 6.48 | * | 6.16 | 3.60 | 0.80 | * |
| 2 | 2.32 | 5.04 | 10.40 | - | * | - | 14.00 | - | * |
| 1 | - | - | - | - | * | - | - | - | * |

NOTE: (-) indicates isotherm could not be closed; * indicates depth not plotted; # indicates all excess temperatures < 2°C.

Table A.9-5. Summary of plume sizes and conditions during all plume surveys (from Ref. 167).

| | | Surface Areas ($10^4 m^2$) For following Isotherms | | | | Lengths (m) for following Isotherms | | | | Tidal Excursion Distance |
|---|---|---|---|---|---|---|---|---|---|---|
| Date | Run | 4°C | 3°C | 2°C | 1°C | 4°C | 3°C | 2°C | 1°C | km |
| 4/15/79 | 1 | - | 1.20 | 5.60 | - | - | 360 | 720 | 2400 | 6.55 |
| 4/15/79 | 2 | - | - | 34.80 | - | - | - | 1180 | 2620 | 6.55 |
| 4/16/79 | 2 | 0.80 | 0.84 | 28.80 | - | 220 | 260 | 1020 | 2280 | 5.91 |
| 4/17/79 | 1 | 0.40 | 4.80 | 17.60 | 196.00 | 160 | 700 | 1300 | 4520 | 6.51 |
| 4/17/79 | 4 | - | 3.60 | 39.60 | - | - | 580 | 1600 | - | -1.71 |
| 4/18/79 | 1 | 1.20 | 4.80 | 17.20 | 256.00 | 280 | 500 | 1200 | 5300 | 7.09 |
| 4/19/79 | 2 | 0.40 | 2.00 | 136.0 | - | 120 | 340 | 3060 | - | 5.00 |
| 4/20/79 | 1 | 0.80 | 2.00 | 375.0 | - | 180 | 600 | 4820 | - | -1.92 |
| 8/06/79 | 2 | 0.20 | 2.24 | 39.92 | 106.88 | 120 | 660 | 760 | - | 5.85 |
| 8/06/79 | 3,4 | - | 0.48 | 7.68 | 574.00 | - | 160 | 680 | - | -2.27 |
| 8/07/79 | 3,4 | 0.64 | 11.12 | 49.94 | - | 120 | 720 | 1380 | - | 6.98 |
| 8/07/79 | 6,7 | 0.32 | - | - | - | - | 290 | 3940 | - | -2.60 |
| 8/08/79 | 2 | - | 0.16 | 1.20 | 4.96 | 60 | 70 | 300 | 490 | 6.32 |
| 8/08/79 | 3,4 | 0.40 | 1.60 | 12.96 | - | 130 | 280 | 1180 | - | 6.32 |
| 8/09/79 | 2 | 0.60 | 1.68 | 7.28 | - | 220 | 1020 | 2480 | 3550 | 7.60 |
| 8/09/79 | 3,7 | 0.72 | 8.08 | 62.56 | - | - | 80 | 320 | - | 7.60 |
| 8/10/79 | 1,7 | - | 0.16 | 1.04 | 4.00 | 210 | 280 | 1020 | - | -2.55 |

Table A.9-5. Continued.

| Date | Run | Plant Heat Rejection MWT | Intake Temperature, °C Max | Intake Temperature, °C Min | Condenser Temperature Rise $\Delta T$, °C | Ambient Temperature $T_a$, °C | Discharge Excess Temperature $\theta_0$, °C |
|---|---|---|---|---|---|---|---|
| 4/15/79 | 1 | 3520 | 10.6 | 8.9 | 5.72 | 9.39 | 5.72 |
| 4/15/79 | 2 | 3520 | 10.6 | 8.9 | 5.72 | 10.33 | 6.19 |
| 4/16/79 | 2 | 3520 | 10.5 | 9.3 | 5.72 | 9.06 | 6.41 |
| 4/17/79 | 1 | 3520 | 10.3 | 9.2 | 5.72 | 8.53 | 6.30 |
| 4/17/79 | 4 | 3520 | 10.3 | 9.2 | 5.72 | 8.98 | 6.68 |
| 4/18/79 | 1 | 3520 | 10.8 | 8.9 | 5.72 | 8.65 | 5.95 |
| 4/19/79 | 2 | 3520 | 11.7 | 9.6 | 5.72 | 10.80 | 5.72 |
| 4/20/79 | 1 | 3520 | 11.7 | 10.6 | 5.72 | 10.10 | 6.25 |
| 8/06/79 | 2 | 3520 | 28.6 | 26.1 | 6.0 | 27.15 | 6.78 |
| 8/06/79 | 3,4 | 3490 | 28.6 | 26.1 | 6.0 | 27.80 | 6.36 |
| 8/07/79 | 3,4 | 3500 | 29.2 | 26.7 | 6.0 | 27.02 | 6.81 |
| 8/07/79 | 6,7 | 3500 | 29.2 | 26.7 | 6.0 | 27.65 | 6.75 |
| 8/08/79 | 2 | 3490 | 28.6 | 25.6 | 6.2 | 27.00 | 5.44 |
| 8/08/79 | 3,4 | 3480 | 28.6 | 25.6 | 6.4 | 27.55 | 6.94 |
| 8/09/79 | 2 | 3500 | 28.9 | 26.1 | 6.6 | 26.79 | 5.96 |
| 8/09/79 | 3,7 | 3480 | 28.6 | 25.6 | 6.4 | 27.00 | 7.66 |
| 8/10/79 | 1,7 | 3500 | 27.5 | 25.3 | 6.4 | 26.94 | 4.83 |

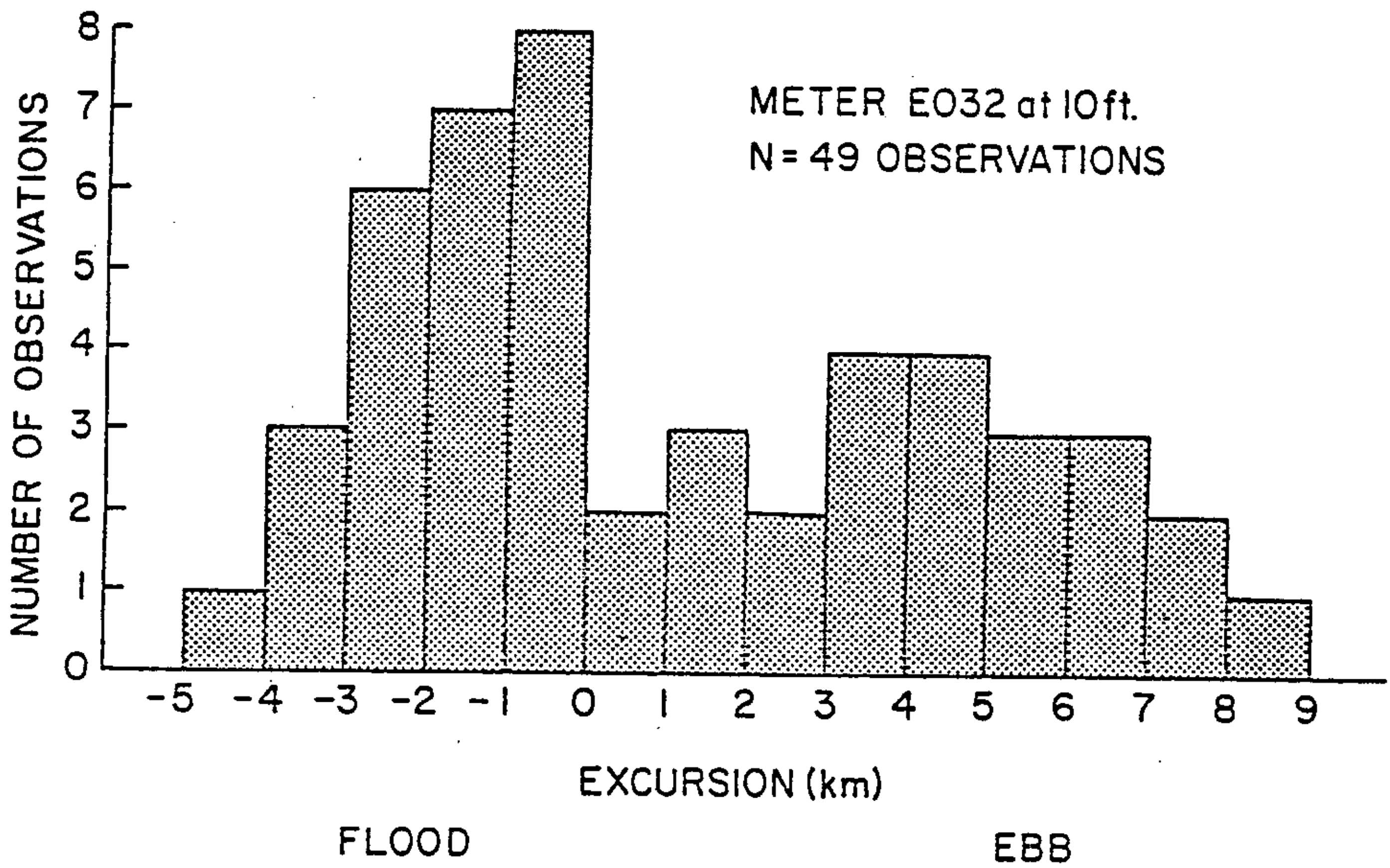


Figure A.9-1. A histogram of measurements of the flood and ebb excursions at ~10 ft (3.05 m) off Calvert Cliffs during April 1979 (from Ref. 167).

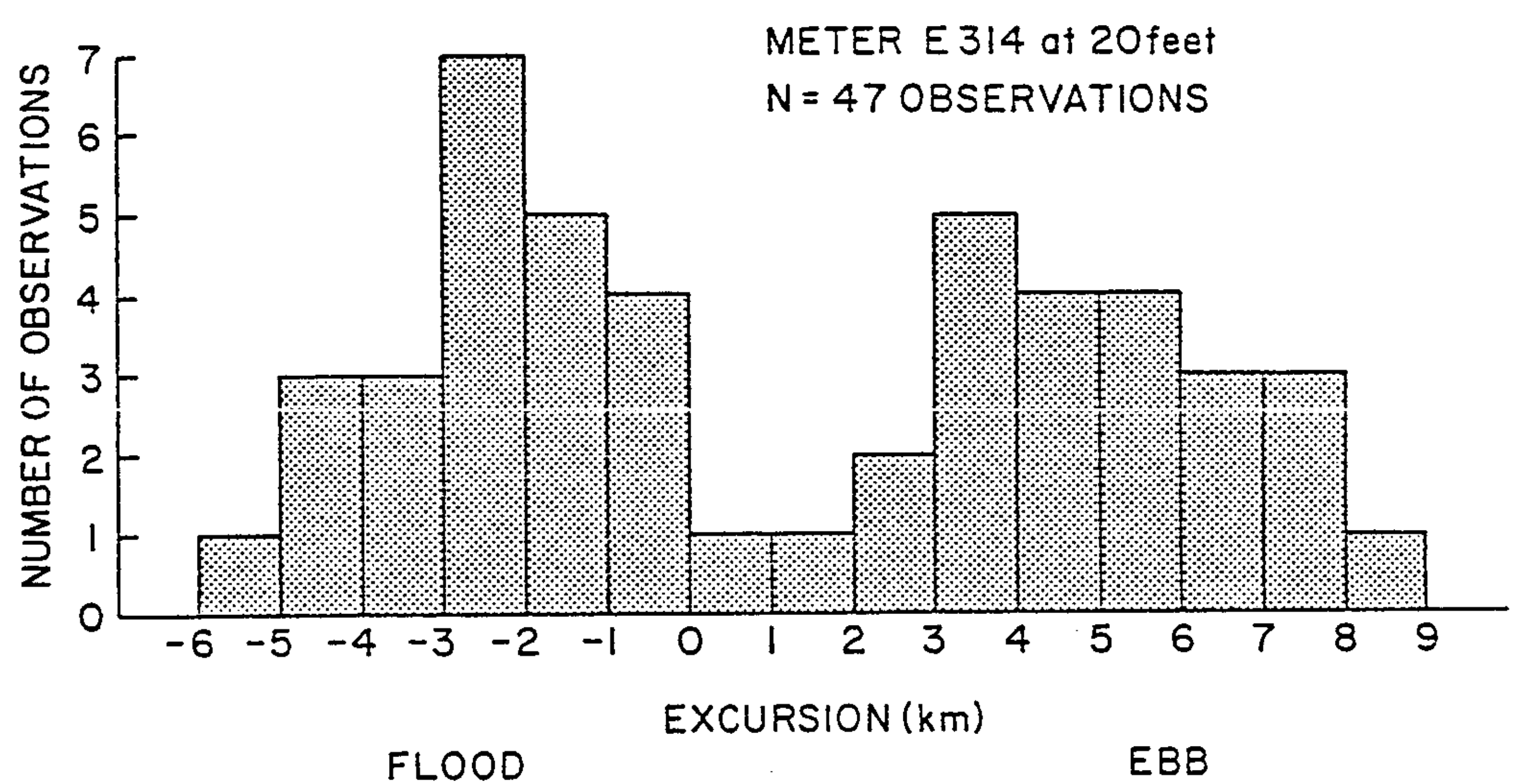


Figure A.9-2. A histogram of measurements of the flood and ebb excursions at ~20 ft (6.1 m) off Calvert Cliffs during April 1979 (from Ref. 167).

# APPENDIX A.10. - FIELD DROGUE STUDIES ON THE CHESAPEAKE BAY NEAR CALVERT CLIFFS, SPRING AND SUMMER 1968

(STP)

## A.10.1. Objective

To determine and document the intensity and direction of tidal currents at various depths and locations in the Bay.

## A.10.2. Data Source

Ref. 29.

## A.10.3. Study History

One-year preoperational study.

## A.10.4. Sampling Methods

Studies were conducted at Chesapeake Beach, the mouths of the Choptank and Patuxent rivers, and in the area of the plant site from Cove Point to Taylors Island. Drogues placed at various depths were attached to floating targets. Targets were tracked by aerial photographs taken at regular intervals. Five such studies were conducted during the spring and summer of 1968. In addition, two visual drogue studies were conducted from survey boats on 12 June 1968. Meteorological and tide level data were also collected.

## A.10.5. Analysis

- Drogue movements were plotted on maps from aerial photographs.
- Drogue velocities were computed from aerial photographic data and drogue movement drawings.

## A.10.6. Results

Summaries of drogue movements and velocities are given in Figures A.10-1 through A.10-4.

## A.10.7. Significance and Critique of Findings

Data are of value for establishing tidal excursion distances in the plant vicinity.

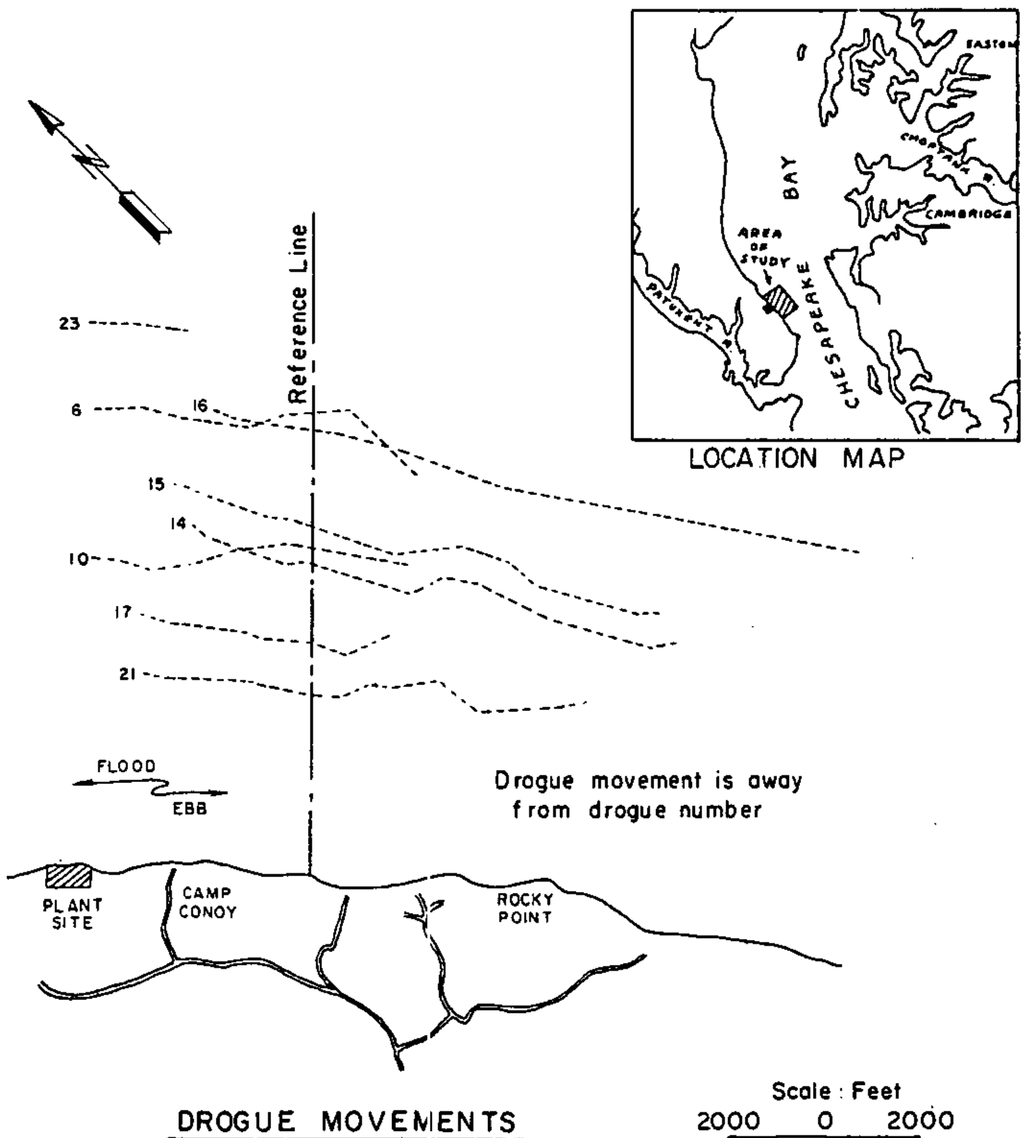


Figure A.10-1. Summary of drogue movements in the Chesapeake Bay, May 31, 1968 (from Ref. 29).

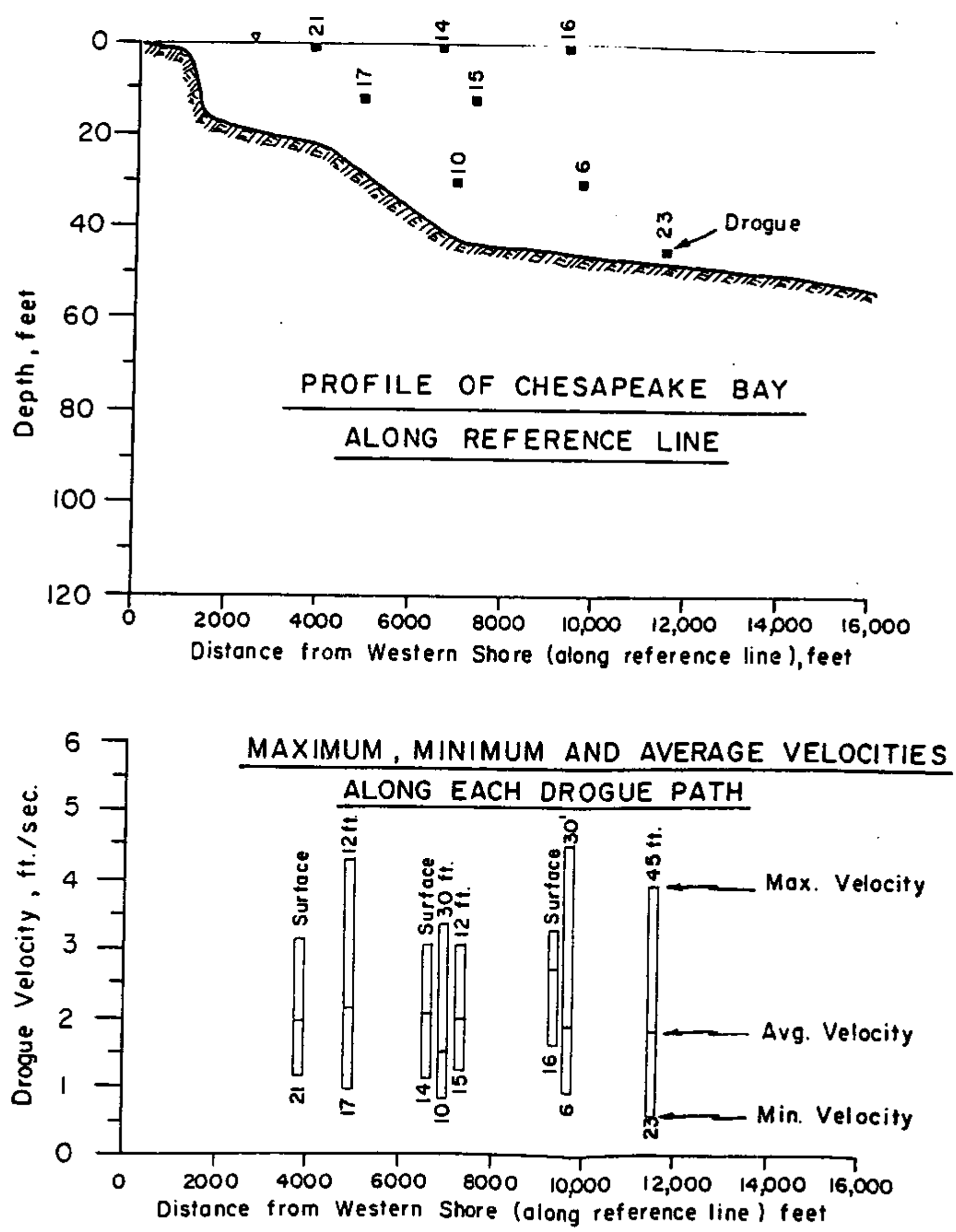


Figure A.10-1. Continued.

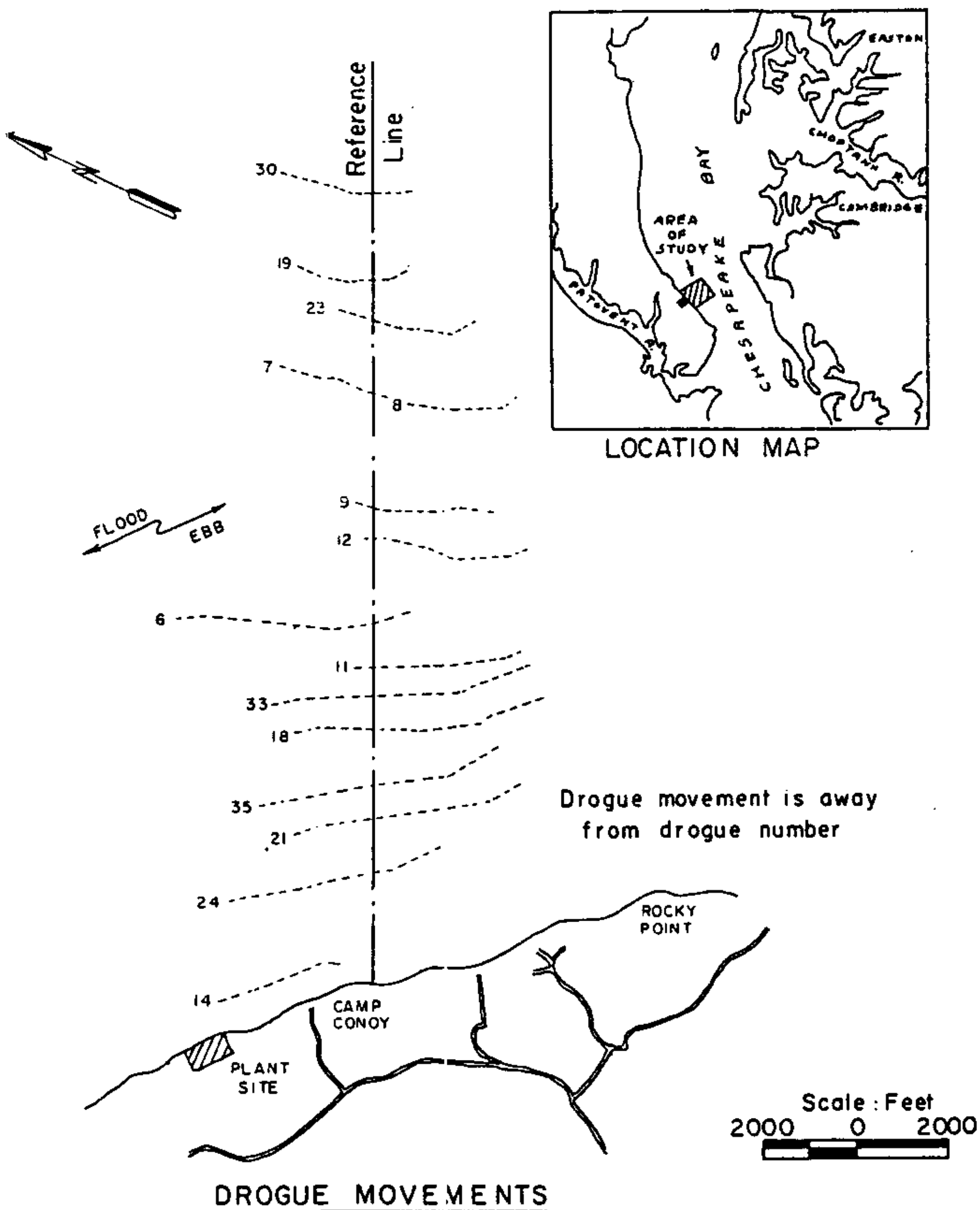


Figure A.10-2. Summary of drogue movements in the Chesapeake Bay, June 13, 1968 (from Ref. 29).

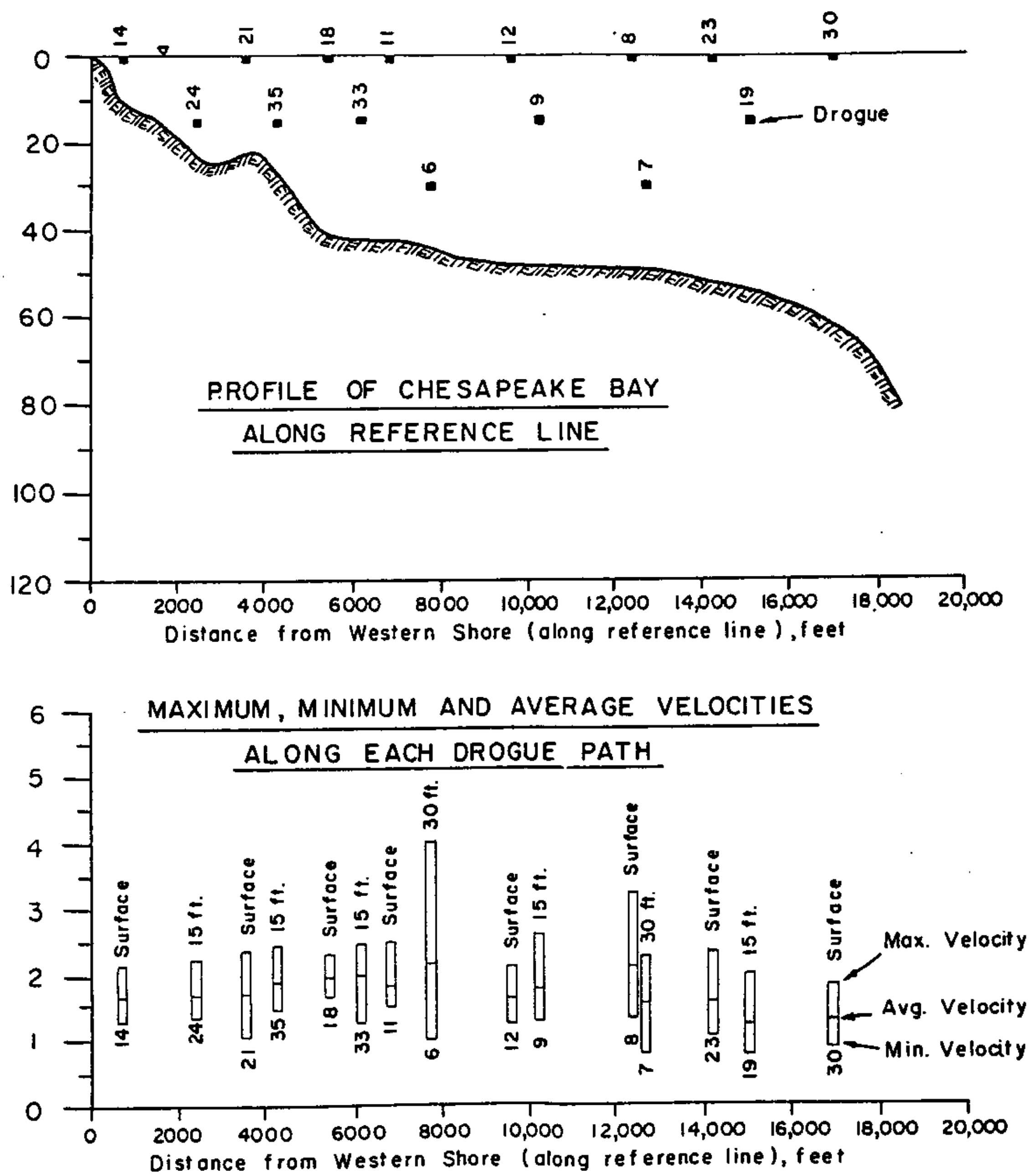


Figure A.10-2. Continued.

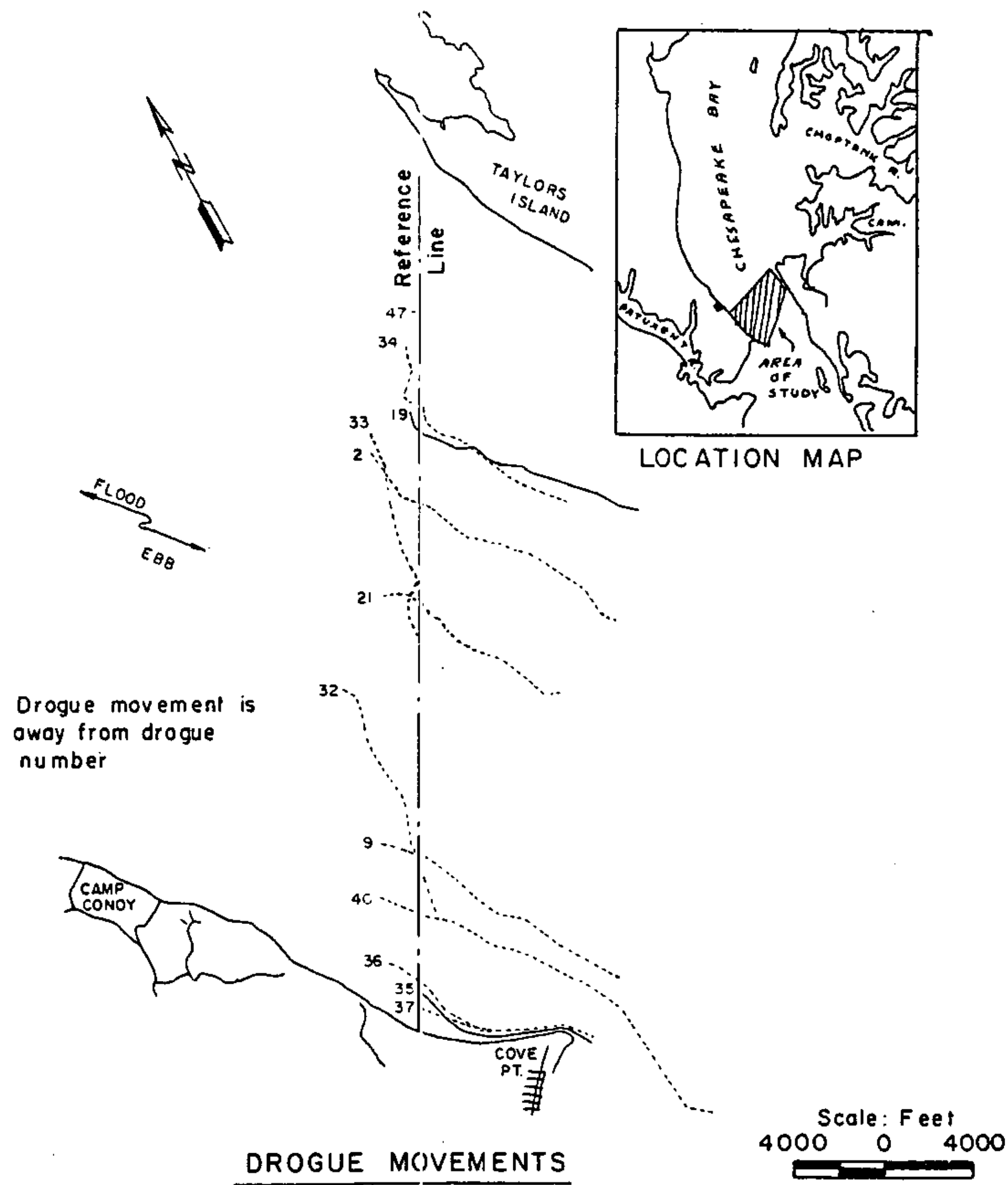


Figure A.10-3. Summary of drogue movements in the Chesapeake Bay, July 23, 1968 (from Ref. 29).

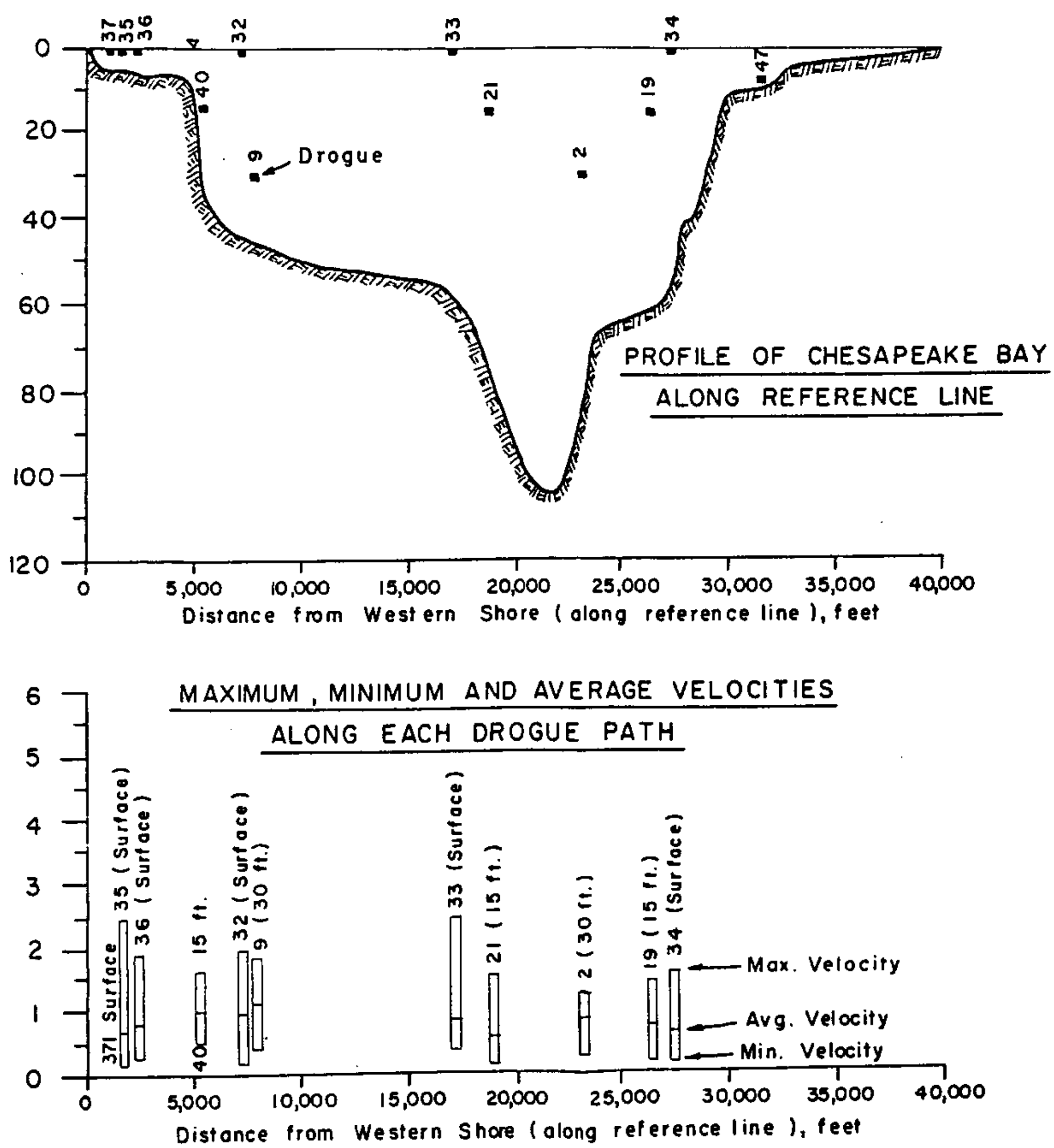


Figure A.10-3. Continued.

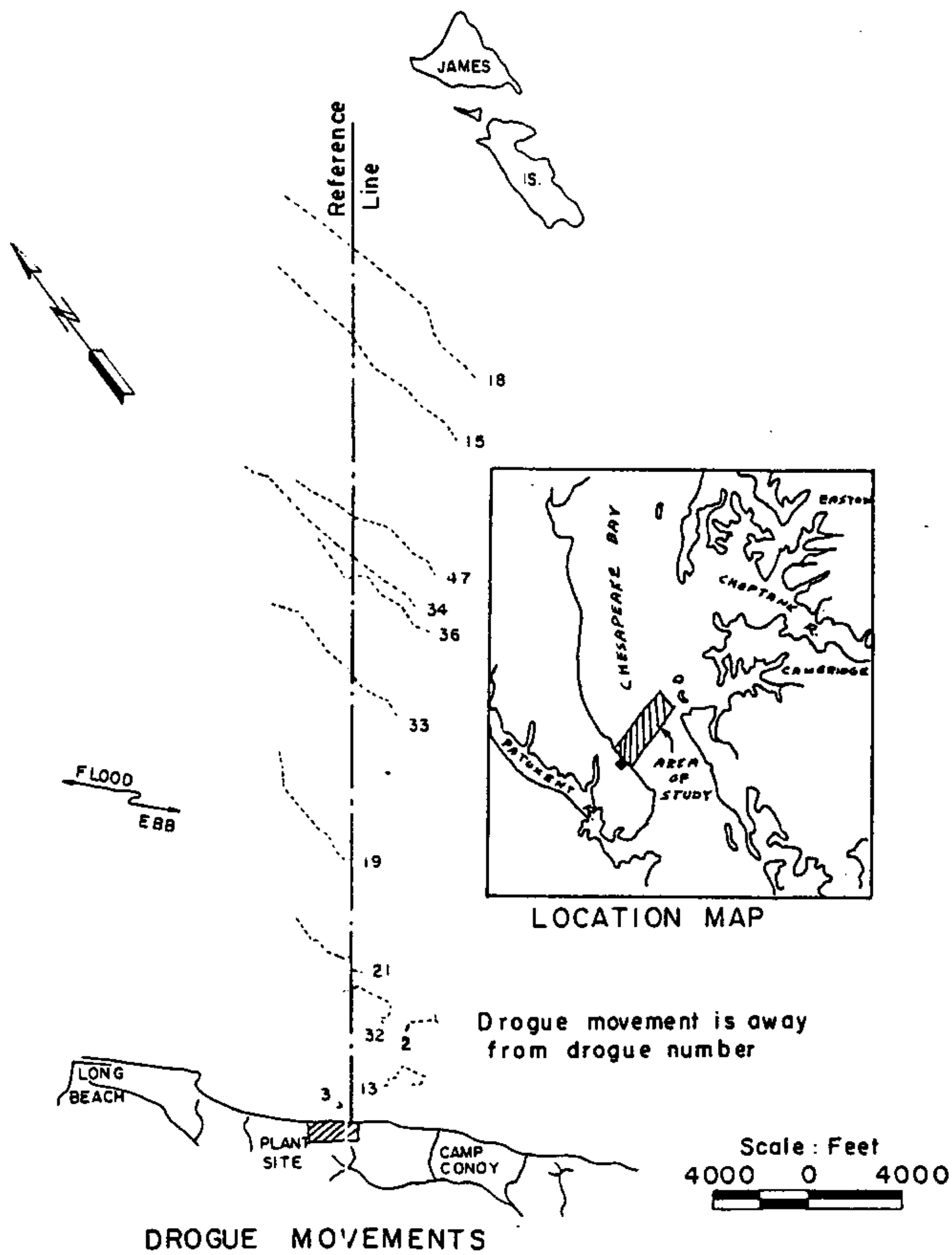


Figure A.10-4. Summary of drogue movements in the Chesapeake Bay, July 24, 1968 (from Ref. 29).

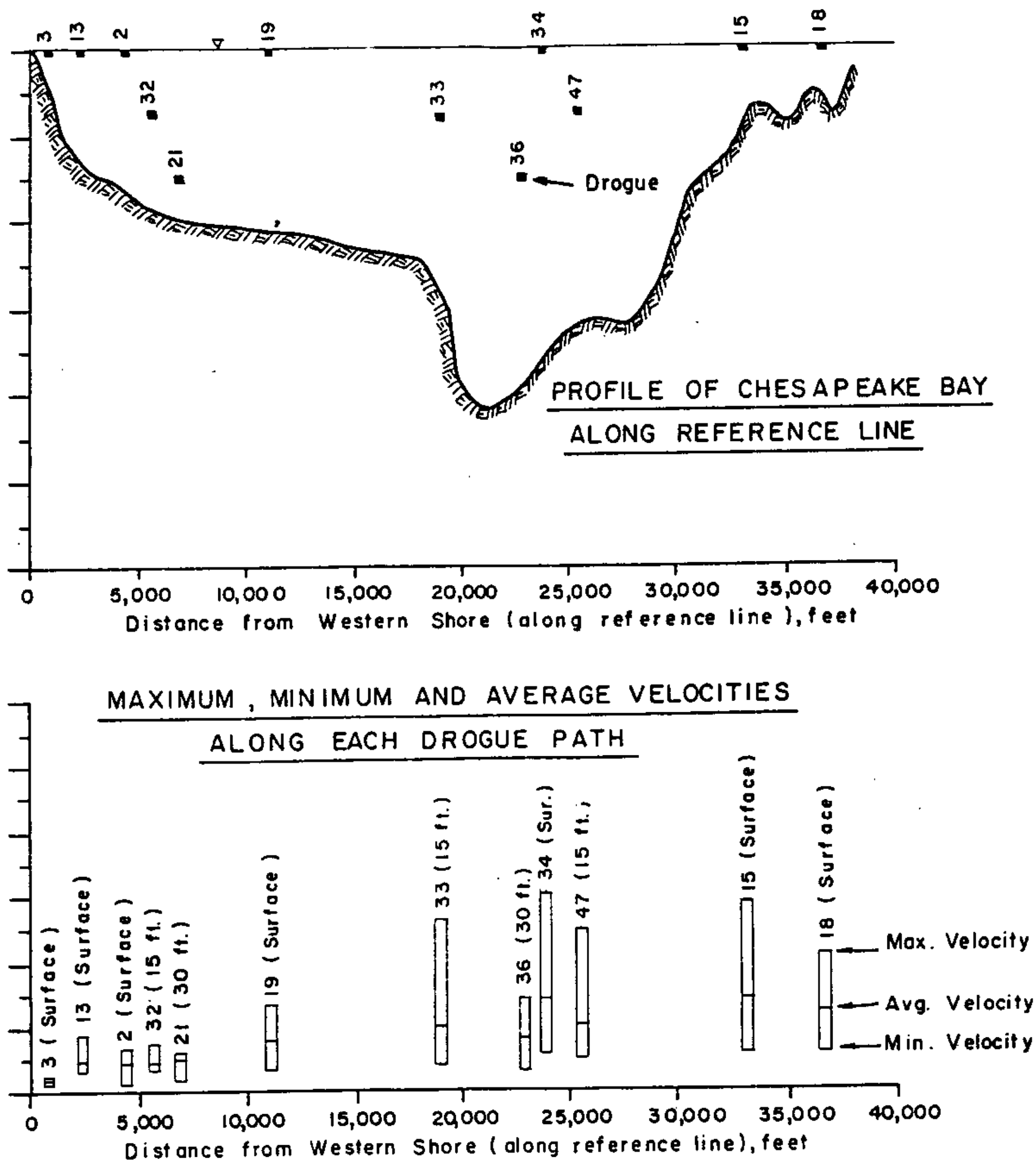


Figure A.10-4. Continued.

# APPENDIX A.11. - CHESAPEAKE BAY CURRENT STUDIES, 1968

(ANSP)

## A.11.1. Objective

To determine the current patterns of the Bay in the vicinity of the plant.

## A.11.2. Data Source

Ref. 70.

## A.11.3. Study History

One-year study.

## A.11.4. Sampling Methods

Seven studies were carried out during spring and summer of 1968--4 on outgoing, 2 on incoming, 1 on turning tides. Surface floats and floats fixed at 10- and 20-foot depths were attached to current drags and released along a transect approximately one mile out from the plant site. Floats were followed by boat, and hourly positions were recorded.

## A.11.5. Analysis

Positions, depths, and distances traversed per hour were marked on copies of U.S. Coast and Geodetic Survey charts.

## A.11.6. Results

- Currents at surface, 10-foot, and 20-foot depths are plotted (e.g., Figs. A.11-1 through A.11-3).
- Figures show current patterns in the Bay on incoming, outgoing, and changing tidal patterns (for examples, see Figs. A.11-1, A.11-4, and A.11-5).
- Several findings indicated that surface currents did not always move at a greater rate than did deeper currents (compare Fig. A.11-3 with Figs. A.11-1 and A.11-2).

### A.11.7. Significance and Critique of Findings

There is some irregularity in paths of drogues released simultaneously. However, in general, the data are of value for establishing typical tidal excursion distances.

SE WIND 5-6 KNOTS, INCREASING TO 14 KNOTS BY AFTERNOON.
3-5 FOOT WAVES BY AFTERNOON.
LOW TIDE 8:29 A.M.
FLOATS PUT IN BETWEEN 8:25 and 8:45 A.M.

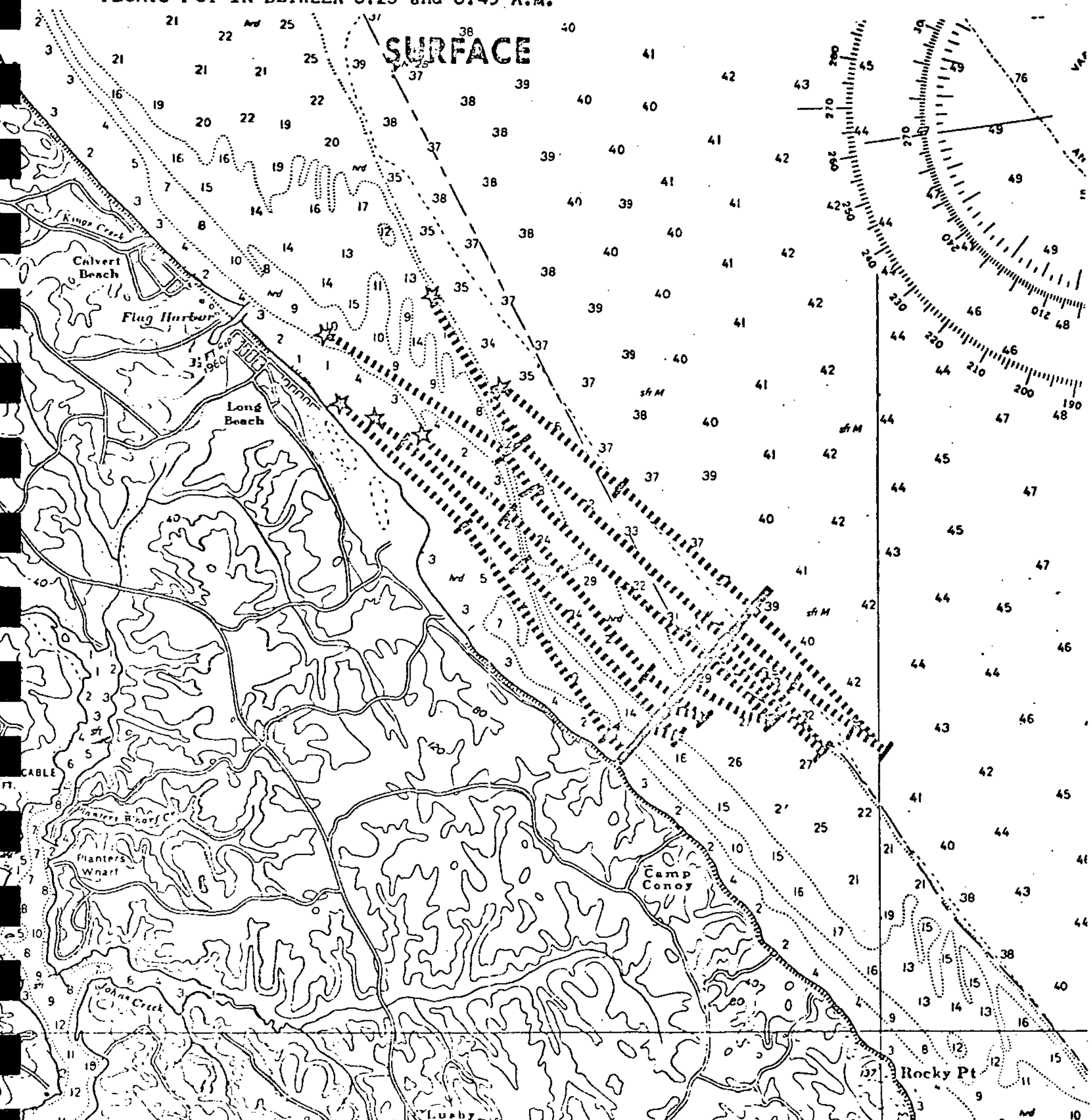


Figure A.11-1. Float studies at surface on Chesapeake Bay, Md., 15 March 1968 with incoming tide (from Ref. 70).

SE WIND 5-6 KNOTS, INCREASING TO 14 KNOTS BY AFTERNOON.
3-5 FOOT WAVES BY AFTERNOON.
LOW TIDE 8:29 A.M.
FLOATS PUT IN BETWEEN 8:25 and 8:45 A.M.

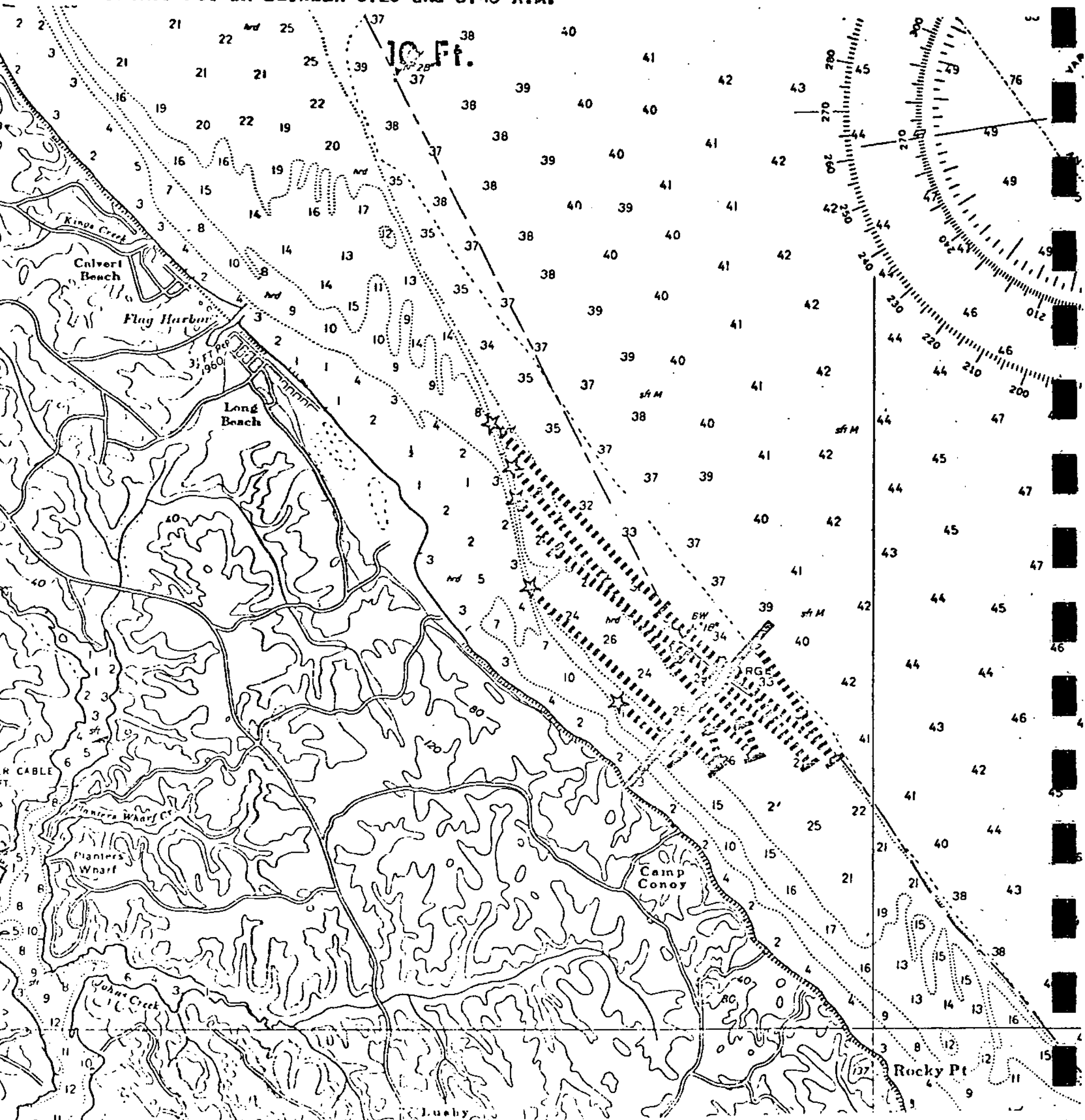


Figure A.11-2. Float studies at 10-ft depth on Chesapeake Bay, Md., 15 March 1968 with incoming tide (from Ref. 70).

SE WIND 5-6 KNOTS, INCREASING TO 14 KNOTS BY AFTERNOON.
3-5 FOOT WAVES BY AFTERNOON.
LOW TIDE 8:29 A.M.
FLOATS PUT IN BETWEEN 8:25 and 8:45 A.M.
? DENOTES LOST FLOAT.

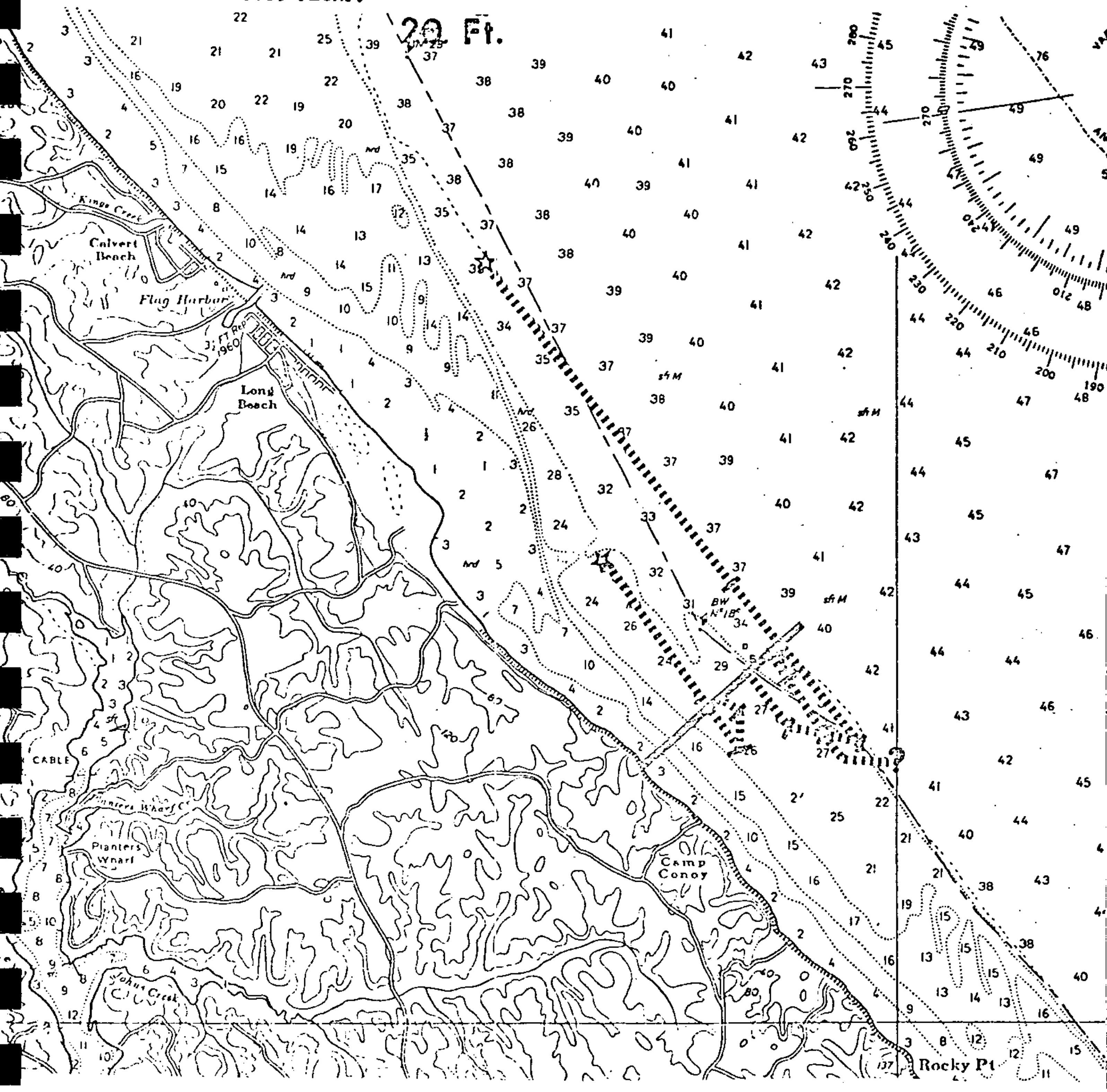


Figure A.11-4. Float studies at 20-ft depth on Chesapeake Bay, Md., 15 March 1968 with incoming tide (from Ref. 70).

WEATHER CLEAR.
LOW TIDE 9:20 A.M.
FLOATS PUT IN BETWEEN 9:20 and 9:40 A.M.

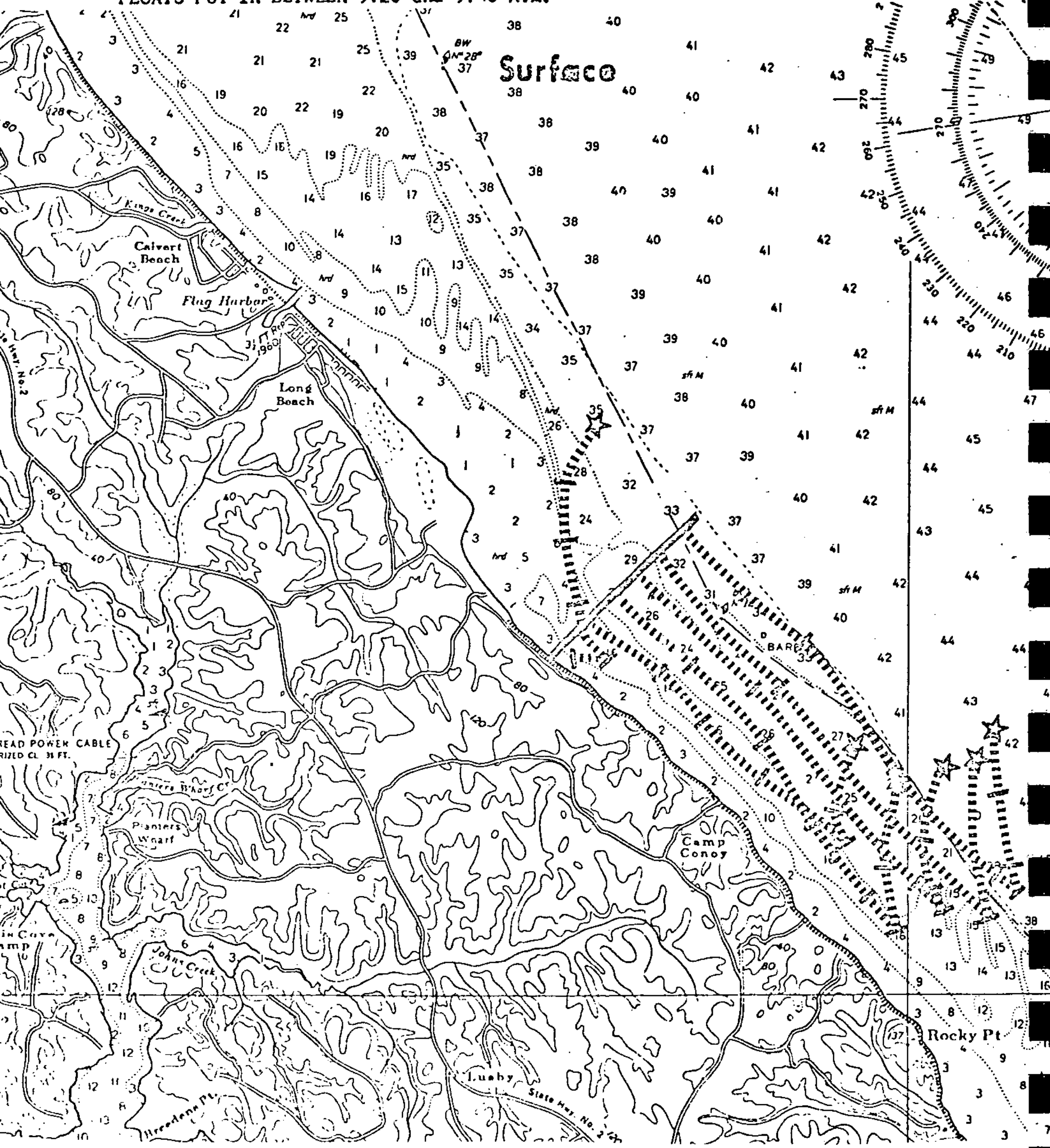


Figure A.11-4. Float studies at surface on Chesapeake Bay, Md., 29 March 1968 with outgoing and turning tide (from Ref. 70).

SW WIND 5-6 KNOTS, WIND SHIFTED AT 12:30 TO SE 10 KNOTS.
FLOATS PUT IN BETWEEN 11:55 A.M. and 12:10 P.M.

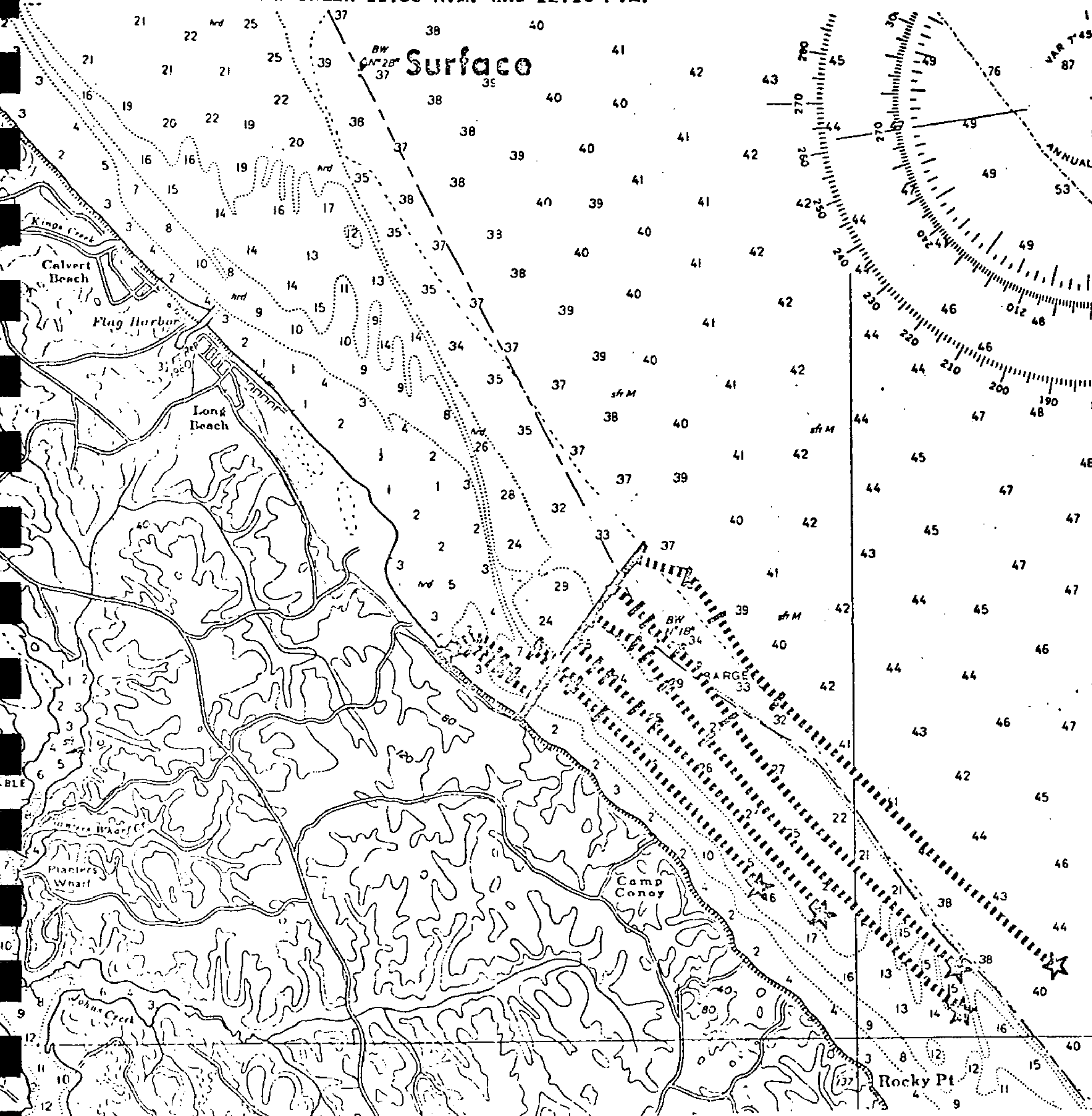


Figure A.11-5. Float studies at surface on Chesapeake Bay, Md., 8 April 1968 with outgoing tide (from Ref. 70).

# APPENDIX A.12. - ANALYSIS OF PPSP CURRENT METER RECORDS

(MMC)

## A.12.1. Objective

To determine some circulation properties from recording current meters deployed near the cooling water intake and discharge regions.

## A.12.2. Data Sources

Refs. 62, 151.

## A.12.3. Study History

CBI conducted a dye dispersion study for PPSP, using the plant discharge as the dye release point (see Appendix A.8). The purpose of the CBI study was to investigate the "intermediate scale" properties of estuarine circulation in the mesohaline portion of the Chesapeake Bay, and to obtain measurements of dye dispersion from the plant effluent for better interpretation of biological distribution data. As part of this study, current meters were deployed for the determination of fluxes and velocity properties up to 10 km away from the discharge point. The six current records analyzed here were specifically obtained to describe the nature of flows induced by the cooling water circulation near intake and discharge locations. This appendix represents primary analysis of these records.

## A.12.4. Sampling Methods

- Six Braincon Recording Histogram current meters were deployed by CBI for PPSP on 18 October 1977. These current meters recorded speed and direction of flow at preset intervals in analog form on photographic film. The data were processed frame-by-frame to yield digital values for speed and direction.

- The deployment statistics for the six current meters in this study are presented in Table A.12-1. Stations S1 and S2 were both located in the intake channel (which has waters approximately 45 ft deep relative to mean low water) and at approximately 100 and 1,600 yards from the curtain wall, respectively. Station S3 was moored approximately 1,000 yards from the discharge beacon, extending along the axis of the discharge conduit. As indicated in Table A.12-1, three meters were deployed at S1, one at S2, and two at S3. The locations of the moorings were reported to the U.S. Coast Guard as:

| | | |
|---|---|---|
| S1 | Lat. 38° 26' 12" | Long. 76° 26' 23" |
| S2 | Lat. 38° 26' 26" | Long. 76° 26' 02" |
| S3 | Lat. 38° 26' 44" | Long. 76° 26' 24" . |

### A.12.5. Analysis

- Data points from all meters were aligned to start at 1450 hours on 18 October 1977, and all computations were performed on records of 32 integral, semidiurnal tidal cycles.

- For analyzing the properties of records, the speed and direction (i.e., the velocity vectors) were broken down into two orthogonal components (x and y). The following choices were made for right-handed coordinate directions:

| Record | Direction of Positive x | Rationale |
|---|---|---|
| S108 | 66.97° magnetic | Perpendicular to curtain wall |
| S128 | 66.97° magnetic | Perpendicular to curtain wall |
| S140 | 66.97° magnetic | Perpendicular to curtain wall |
| S208 | 73.22° magnetic | Net flow approximately zero in x direction |
| S308 | 73.22° magnetic | Arbitrary |
| S325 | 73.22° magnetic | Arbitrary |

Thus, from each pair of records of speed and direction, two scalar records were generated in an orthogonal coordinate system.

- For investigating some properties of the records, scattergrams were generated in the designated coordinate systems, using a bivariate plot program, including elementary regression analysis. Regressions were carried out on the entire x-y records and separately on the portions with positive and negative y components. The S108 records were linearly interpolated for time intervals of 20 minutes.

- A modified version of the time series analysis program BMD02T (Ref. 151) was applied to all x and y components. Autocovariance, power spectra, and cross-covariances were obtained for various records.

- The raw data were also smoothed, using a Gaussian filter with a standard deviation of 8 hours. The semidiurnal tidal signal was efficiently removed by this filter. Diurnal periodicities were not significant in the raw data.

## A.12.6. Results

- The following net flow vectors are diagrammed in Fig. A.12-1:

| Station/Depth | S108 | S128 | S140 | S208 | S308 | S325 |
|---|---|---|---|---|---|---|
| Speed (cm/s) | 3.7 | 8.8 | 14.7 | 10.6 | 3.6 | 6.4 |
| Direction (°M) | 319 | 259 | 250 | 166 | 46 | 12 |

These are mean, nontidal flows averaged over 32 tidal cycles. As can be seen from these values and Fig. A.12-1, all the net flows near the curtain wall have some component flowing into the intake embayment, with practically all flow directed into the embayment at the 40-ft depth. The profile with depth indicates that water is being preferentially withdrawn from layers below the curtain wall depth (28 ft). The surface layer flow (at the curtain wall) at 8 ft is directed to a direction that closely parallels the curtain wall. This flow is contrary in direction from the expected nontidal estuarine flow in the surface layer. Presumably, this may be an induced flow replenishing some of the surface water being entrained by the discharge jet and being transported offshore. Infrared photographs taken in 1978 at the site (Appendix A.7) show current patterns seemingly satisfying continuity in the surface layer by providing water masses for transport offshore by discharge jet entrainment.

- The surface net flow at station S2 does not show any significant influence of cooling water intake. This is to be expected, since the location is 1,600 yards from the curtain wall at 8 ft, and water is being preferentially withdrawn from greater depths. However, the net flow of 10.6 cm/s seems to be an excessive surface net flow, giving rise to the possibility that the discharge jet's radial momentum is being manifested here.

- The surface (8-ft) and 25-ft net flows at station S3 seem to be influenced most by the initial jet discharge direction. There is some possibility of net lower-layer estuarine flow influencing the direction at 25 ft.

- The following are root mean square velocities (approximate tidal amplitudes) at the various sampling points:

| Station/Depth | S108 | S128 | S140 | S208 | S308 | S325 |
|---|---|---|---|---|---|---|
| Direction of +x (°M) | 66.97° | 66.97° | 66.97° | 73.22° | 73.22° | 73.22° |
| Standard deviation x (cm/s) | 14.0 | 7.5 | 6.7 | 8.9 | 9.6 | 9.2 |
| Standard deviation y (cm/s) | 17.7 | 8.0 | 5.8 | 18.4 | 26.5 | 16.9 |

It is clear that amplitudes of tidal velocities typically do not exceed 30 cm/s during the measurement period and that the induced bottom flow near the curtain wall and at the surface at S2 approach tidal amplitude values.

- The autocovariance values for all meters show semidiurnal and diurnal periodicities. However, the power in the diurnal component is relatively small.

- The cross-covariances of records with respect to the x and y components of S140 are weak, and therefore, phasing properties are difficult to specify. Generally, all x-components lead the S140 x-component, and all y-components lead the S140 y-component.

## A.12.7. Significance and Critique of Findings

- During the measurement period (October through November, 1977), the intake flow is preferentially withdrawn from the bottom layers of the intake channel (and of the Bay). This implies generally higher salinities being withdrawn and discharged by the jet into surface waters.

- The local flow fields induced by the intake and discharge of cooling water are comparable in magnitude to both tidal and nontidal flows in the Bay.

Table A.12-1. Deployment statistics for current meters

| Station | Depth (ft) | Designation | Deployment Date | Recording Interval | Number of Data Points | Location |
|---|---|---|---|---|---|---|
| S1 | 8 | S108 | 10/18/77 | 40 min | 603 | 100 yd from curtain wall (in intake channel) |
| S1 | 28 | S128 | 10/18/77 | 20 min | 1207 | 100 yd from curtain wall (in intake channel) |
| S1 | 40 | S140 | 10/18/77 | 20 min | 1206 | 100 yd from curtain wall (in intake channel) |
| S2 | 8 | S208 | 10/18/77 | 20 min | 1206 | 1,600 yd from curtain wall (in intake channel) |
| S3 | 8 | S308 | 10/18/77 | 20 min | 1206 | 1,000 yd from discharge beacon, in line with discharge conduit axis |
| S3 | 25 | S325 | 10/18/77 | 20 min | 1206 | 1,000 yd from discharge beacon, in line with discharge conduit axis |

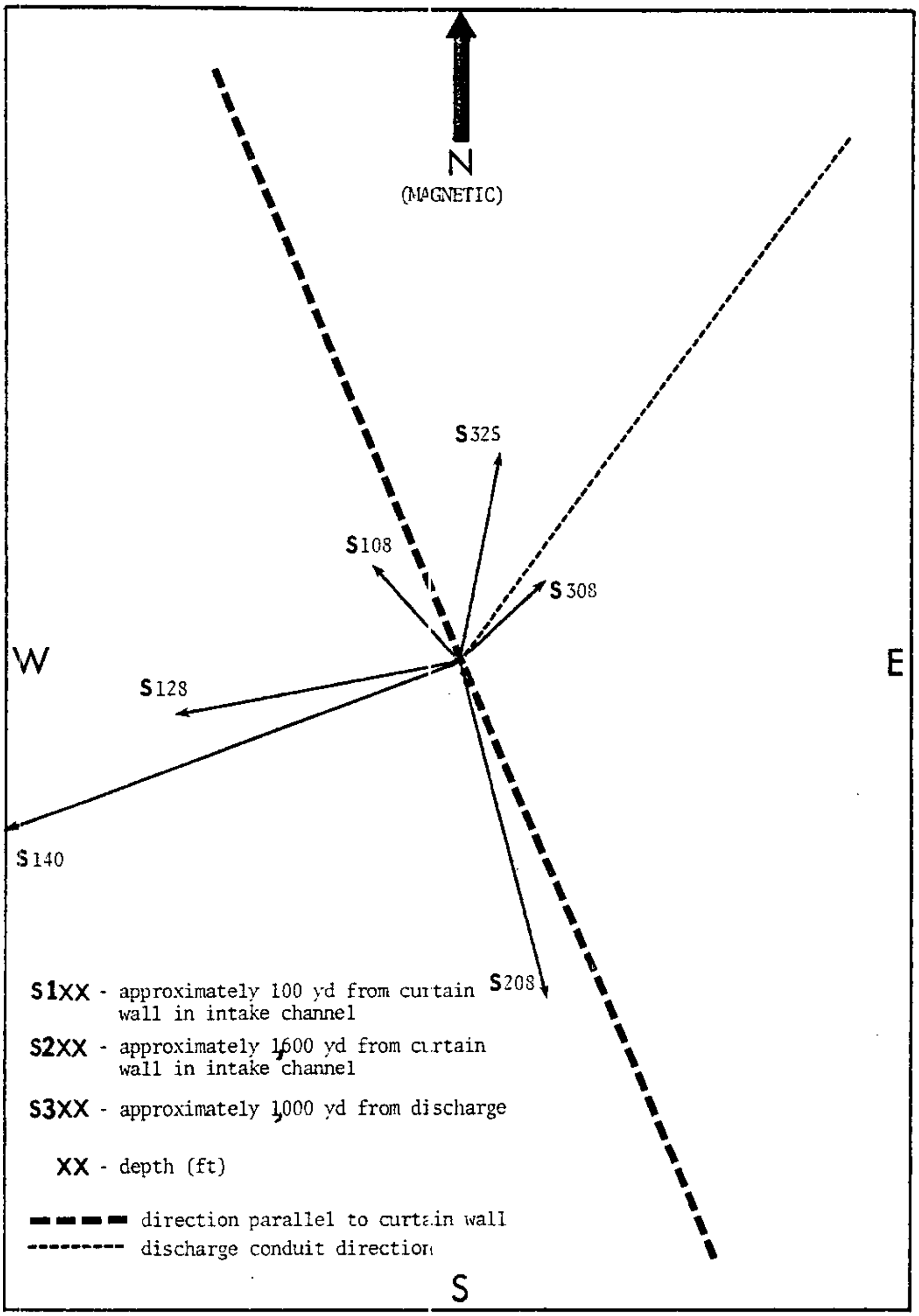


Figure A.12-1. Computed net flows for 32 tidal cycles.

# APPENDIX A.13. - EFFECT OF CURTAIN WALL ON INTAKE WATER QUALITY

(H.H. Carter and S.R. Rives, CBI)

## A.13.1. Objective

To determine the effect of the removal of panels from the curtain wall on cooling water source and quality.

## A.13.2. Data Source

Ref. 51.

## A.13.3. Study History

First year of a four-year series of studies (see also Appendices A.14 through A.16).

## A.13.4. Sampling Methods

- Sampling was performed from August through September 1975.
- Recirculation was measured at the intake after dye was released in the discharge.
- Flow under and through the curtain wall was measured with a current meter array. Temperature profiles at the curtain wall were monitored continuously. Oxygen and salinity profiles were measured irregularly.
- Three phases of study included:

  -- Phase 1, no panels removed from the curtain wall,

  -- Phase 2, 4 panels removed from the ends of the curtain wall,

  -- Phase 3, 2 panels removed from the center of the curtain wall.

## A.13.5. Analysis

- The fraction of total flow that is recirculated is computed as

$$\frac{C_i}{C_o}$$

where $C_i$ = dye concentration in intake flow
$C_o$ = dye concentration in discharge flow.

- Velocity scatter diagrams were plotted for each current meter. Correlations between velocities at different locations were calculated, and flux of water under and/or through the curtain wall was calculated.

- Vertical distributions of temperature, salinity, and D.O. were plotted and visually compared with wind data.

## A.13.6. Results

- Maximum recirculation during Phase 2 was 7.9%, and during Phase 3, it was 11.5%.

- Flow

  -- Periodic vertical oscillations of the pycnocline relative to location of the lower curtain-wall edge controls the vertical distribution of inflow; when the pycnocline is deep, flow through open curtain-wall panels is increased.

  -- For each center panel removed from the curtain wall, flow beneath the curtain wall was reduced by about 12%.

- Vertical profiles

  -- The depth of low oxygen water may vary with wind direction, rising near the surface with offshore (westerly) winds.

  -- Oxygen, temperature, and salinity profiles are correlated.

## A.13.7. Significance and Critique of Findings

Removal of curtain-wall panels increases recirculation and also enhances the withdrawal of surface waters for cooling. This action would ensure that intake embayment oxygen levels remain high, but it also would tend to increase the temperature of water used for cooling.

# APPENDIX A.14. - INTAKE FLOW CHARACTERISTICS

(H.H. Carter and S.R. Rives, CBI)

## A.14.1. Objective

To determine the nature of cooling water flow at Calvert Cliffs during periods when the Chesapeake Bay is stratified.

## A.14.2. Data Source

Ref. 52.

## A.14.3. Study History

Second year of a four-year series of studies (see also Appendices A.13, A.15, and A.16).

## A.14.4. Sampling Methods

Fourteen current meters were deployed beneath and within open panel sections of the curtain wall from May to August 1976. Measurements were made with no curtain-wall panels removed, side panels only removed, and both side and center panels removed.

## A.14.5. Analysis

Current meter vectors were resolved into components along axes normal to the curtain wall, and simple arithmetic averages were calculated over specific time intervals. Scatter diagrams for each current meter were plotted.

## A.14.6. Results

- Mean vector values for each study period are presented in Figs. A.14-1 through A.14-5.
- Currents under and/or through the curtain wall are highly variable in speed, but they are coherent.
- Speed through any open panel will not exceed 60 cm/s.
- Removing side panels does not provide for surface flow, but it does provide egress for fish. When D.O. values declined during this study, few fish were impinged, while apparent densities in the embayment declined markedly.

### A.14.7. Significance and Critique of Findings

Essentially, findings confirm those of the 1975 study.